ERRATA

1. Page 109 second para, 3rd sentence: (as cited in Currie (2007, page 2.9)) for (as cited in Currie (2007, page 2.9).

2. Page 172 second para, 1st sentence: "Information from ABS (2006i)..." for "Information from ABS (2006l)...".

3. Page 173 first para, 2nd sentence: "ABS's (2006i) data..." for "ABS's (2006l) data...".

4. Page 183 first para, 1st sentence: "As highlighted earlier, ABS (2006i) data..." for "As highlighted earlier, ABS (2006l) data...".

5. Page 292 third to last line: "absolute drop in the CBD's GRP in dollars" for "absolute drop in the CBD's GRP in dollar".

6. Page 329 first para, 1st sentence: "Conventional travel elasticities" for "Conventional travel elasticites".

ADDENDUM

1. Page 4. Add footnote to "accessibility" in last sentence of 1st para: "Accessibility refers to the ease with which people can access services and activities in an area. It is measured in terms of generalised transport costs (Litman, 2008a)".

2. Page 53. Add footnote at the end of the 2nd para: "Shefer (1973) defined urban scale as employment population".

3. Page 152 first para, 1st sentence: amend "Litman (2008)" to "Litman (2008b)".

4. Page 289 second para, 4th sentence: delete "flow-on" and read "TERM's results suggest that the flow-on effects to the other regions...".

5. Page 423. Add new reference: "Litman, T. (2008a), Evaluating Accessibility for Transportation Planning, Victoria Transport Policy Institute".

6. Page 423 fourth reference: amend "Litman, T. (2008), Transportation Elasticities – How Prices and Other Factors Affect Travel Behaviour" to "Litman, T. (2008b), Transportation Elasticities - How Prices and Other Factors Affect Travel Behaviour ".

Exploring the Economic Impacts of Agglomeration Economies in Urban Rail Projects

By

Tat Meng Gwee

B.Eng., M.Sc.

Submitted for the degree of

DOCTOR OF PHILOSOPHY

Institute of Transport Studies

Department of Civil Engineering, Monash University

November 2010

Dedicated to

Soo Leng, Sarah, Ethan and Eamon (arriving in January 2011)

for their love and encouragement

Table of Contents

List of Figures viii
List of Tables xii
Abstract xvii
Author's Declaration xix
Acknowledgements xx
Copyright Notices xxii

1. Chapter 1: Introduction 1
1.1 Background and Motivation 1
1.2 Research Aim and Objectives 3
1.3 Scope of Study 3
1.4 Research Contributions 5
1.5 Thesis Structure 6

2. Chapter 2: Literature Review 9
2.1 Introduction 9
2.2 Wider Economic Benefits in Transport Projects 10
2.3 Theory of Agglomeration 11
2.3.1 Definition 11
2.3.2 Drivers and Effects of Agglomeration 11
2.3.3 Classification of Agglomeration Economies 13
2.3.3.1 Internal Scale Economies 13
2.3.3.2 Localisation Economies 14
2.3.3.3 Urbanisation Economies 15
2.4 Agglomeration Effects of Transport Projects 16
2.4.1 Assessment 21
2.5 Estimating Agglomeration Effects – Alternative Methodologies 23
2.5.1 Alternative Measurement Methodologies 23
2.5.1.1 Comparative Analysis 23
2.5.1.2 Surveys and Interviews 24
2.5.1.3 Economic Analysis 25
2.5.1.4 Computable General Equilibrium Modelling 27
2.5.1.5 Assessment 29
2.5.2 Comparative Assessment of International CBA Practices on Urban Rail 31
2.5.3 Critique on Double-Counting Issue 35

Table of Contents

2.6 A Review of Past Studies 36
2.6.1 Studies that found a Positive Link between Public Infrastructure Provision and Productivity 38
2.6.1.1 Assessment 41
2.6.2 Studies that found a Weak Link between Public Infrastructure Provision and Productivity 44
2.6.2.1 Assessment 45
2.6.3 Studies that Considered both the effects of Agglomeration and Public Infrastructure Provision on Productivity 47
2.6.3.1 Assessment 49
2.6.4 Studies that made use of Spatial Data and Density Measures to estimate Agglomeration Economies 51
2.6.4.1 Assessment 57
2.6.5 Studies that used CGE Models to estimate the Wider Economic Impacts of Major Transport Infrastructure 61
2.6.5.1 Applications of CGE Modelling to estimate the Wider Economic Impacts of Major Transport Infrastructure 64
2.7 Synthesis and Knowledge Gaps 66
2.8 Summary 68

3. Chapter 3: Research Methodology 70
3.1 Introduction 70
3.2 Methodological Concept 71
3.3 Methodological Details 76
3.3.1 Secondary Research and Data Analyses 76
3.3.2 Transport Modelling 78
3.3.3 Melbourne CBD Employer Survey 80
3.3.4 Computable General Equilibrium Modelling 81
3.3.5 Comparative Assessment 82
3.4 Summary 82

Table of Contents

4. Chapter 4: Case Study - Travel Issues to Melbourne Central Business District 84

4.1 Introduction 84

4.2 Melbourne CBD and its Employment Profile 85

4.2.1 Melbourne CBD's Employment Profile 87

4.2.2 Melbourne CBD's Employment Growth 89

4.3 Travel Characteristics of CBD Employees 92

4.3.1 Overview of Transport Network serving Melbourne CBD 92

4.3.2 Travel Pattern of CBD Employees 94

4.3.3 Car Ownership Level of CBD Employees who use Rail 98

4.3.3.1 Employees with No Private Car Access 99

4.3.3.2 Employees with Limited Private Car Access 101

4.3.3.3 Employees with Ready Private Car Access 102

4.3.3.4 Assessment 103

4.4 Congestion Status of Melbourne Train Network 104

4.4.1 Methodology 105

4.4.2 Assessment – Rail Capacity Constraint Status 107

4.5 Justification to Adopt Melbourne CBD as a Case Study 109

4.5.1 International Evidence 109

4.5.2 Comparative Assessment of Five Major Australian CBDs 112

4.5.2.1 Methodology 113

4.5.2.2 Results 114

4.6 Summary 115

5. Chapter 5: MITM Modelling 117

5.1 Introduction 117

5.2 Overview of MITM 122

5.2.1 MITM Model Structure 122

5.2.2 Modelling Process and Outcome 124

5.2.2.1 Trip Generation 125

5.2.2.2 Trip Distribution 127

5.2.2.3 Mode Split 128

5.2.2.4 Trip Assignment 130

Table of Contents

5.3 Secondary Research – CBD Commuter Behaviour and Rail Capacity Constraint 131
5.3.1 Assessment – Alternatives for Work Trips in times of Rail Capacity Constraint 137
5.3.1.1 Alternative Choices for Affected Rail Commuter Trips 137
5.3.1.2 Alternative Choices for Affected Auto Commuter Trips 140
5.4 MITM Modelling Approach 144
5.5 Analysis of MITM Output 146
5.5.1 Generalised Cost of Automobile Trips into the CBD 147
5.5.2 Average Travel Times of Automobile Trips into the CBD 150
5.6 Assessment – Estimation of Potential Trip and Employment Suppression Impacts associated with a Rail Capacity Constraint 151
5.6.1 Secondary Research – Evidence from Trip Elasticity Studies 151
5.6.2 Rail Trip Suppression Impact 153
5.6.2.1 Methodology 153
5.6.2.2 Results 154
5.6.3 Automobile Trip Suppression Impact 155
5.6.3.1 Methodology 155
5.6.3.2 Results 156
5.6.4 Resultant Impact to Melbourne CBD's Employment 157
5.6.5 Interpretation of MITM Output 159
5.7 Summary 161

6. Chapter 6: Melbourne CBD Employer Survey 163
6.1 Introduction 163
6.2 Survey Approach 165
6.2.1 Questionnaire Design 167
6.2.2 Pilot and Main Survey 168
6.3 Analysis of Survey Results 169
6.3.1 Remuneration Impacts 171
6.3.2 Short Term Employment Impacts 175
6.3.3 Longer Term Employment Impacts 178

Table of Contents

6.3.4 Assessment – Accuracy of the Survey Findings 180
6.3.4.1 Survey Sample 180
6.3.4.2 Assessing Remuneration Impacts 183
6.3.4.3 Assessing Short Term Employment Impacts 185
6.4 Key Observations and Feedback 186
6.5 Summary 189

7. Chapter 7: Secondary Data Analysis 190
7.1 Introduction 190
7.2 Selection of Cities 192
7.3 Analysis Approach 194
7.4 Hypotheses 198
7.5 Statistical Assessment 202
7.5.1 Assessment Framework 202
7.5.1.1 Sample Size 203
7.5.2 Multiple Regression 203
7.5.2.1 Method of Regression 203
7.5.2.2 Results 204
7.5.3 Elasticity Evaluation 207
7.5.3.1 CBD Employment Size and GRP 208
7.5.3.2 CBD Employment Size and Rail Capacity Provision 211
7.5.3.3 CBD GRP and Rail Capacity Provision 214
7.6 Critique of Data Set 216
7.7 Summary 219

8. Chapter 8: TERM Modelling 221
8.1 Introduction 221
8.2 The TERM Model 226
8.2.1 Database Structure 227
8.2.2 Theoretical Structure 231
8.2.2.1 Sourcing Mechanism in TERM 232
8.2.2.2 Industry Demands and Supply 234
8.2.2.3 Household Demands 235
8.2.2.4 Investment Demands 235
8.2.2.5 Government Demands 236

Table of Contents

8.2.2.6 Export Demands....237
8.2.2.7 Margins....237
8.2.2.8 Market Clearing Conditions....238
8.2.2.9 Gross Regional Product....238
8.2.3 Simulation Process and Outcome of TERM....238
8.3 Modifications to TERM....241
8.3.1 Model Limitations....241
8.3.2 Modelling Assumption and Model Alternations....243
8.3.2.1 Key Modelling Assumption....243
8.3.2.2 Model Alternations....244
8.3.2.3 Additional Equations for Long-Run Simulations....249
8.4 The TERM Modelling Approach....251
8.4.1 Wage – Employment Shock Approach....251
8.4.1.1 Back-Of-The-Envelope (BOTE) Model....253
8.4.1.2 Experiment....255
8.4.2 Productivity Shock Approach....257
8.5 Estimation of Productivity Shocks....261
8.5.1 Methodology....261
8.5.2 Applications of Productivity Shocks on TERM....266
8.6 TERM Output....267
8.6.1 Overview....267
8.6.2 Short-Run Economic Impact....269
8.6.2.1 Direct Effects....270
8.6.2.2 Inter-Regional Flow-On Effects....274
8.6.2.3 Net Effects on the Nation....275
8.6.2.4 Impacts on Various Sectors....275
8.6.3 Long-Run Economic Impact....278
8.6.3.1 Direct Effects....280
8.6.3.2 Inter-Regional Flow-On Effects....282
8.6.3.3 Net Effects on the Nation....285
8.6.3.4 Impacts on Various Sectors....285
8.7 Summary....288

Table of Contents

9. Chapter 9: Agglomeration Estimates – Approach 290
9.1 Introduction 290
9.2 Estimation based on Proximity Impacts – PETE Method 292
9.2.1 Economic Value of Agglomeration Dis-benefits 292
9.2.2 Critique of the PETE Method 295
9.3 Estimation based on Employer Suppression Impacts 297
9.3.1 Estimation based on MITM Output 299
9.3.1.1 Estimation of Productivity Elasticity for Melbourne CBD 299
9.3.1.2 Economic Value of Agglomeration Dis-benefits 301
9.3.2 Estimation based on CBD Employer Survey Findings 302
9.3.3 Estimation based on Secondary Data Analysis Findings 303
9.4 Summary 304

10. Chapter 10: Agglomeration Estimates – Comparative Assessment 306
10.1 Introduction 306
10.2 Short Term Impacts 308
10.3 Long Term Impacts 312
10.4 Summary 317

11. Chapter 11: Conclusions 319
11.1 Introduction 319
11.2 Overview of Research Framework 319
11.3 Key Results 322
11.4 Research Contributions 324
11.5 Assessment of Research Approach 328
11.6 Suggestions for Future Research 330

Appendix A: Congestion Status of Melbourne Train Network 334
Appendix B: Comparative Assessment of Australian CBDs 340
Appendix C: Field Survey Report – Melbourne CBD Employer Survey 345
Appendix D: Secondary Data Analysis 374
Appendix E: Theoretical Structure of TERM 384
Appendix F: Back-Of-The-Envelope Analysis 399
Appendix G: Estimation of Productivity Shocks 403
References 409

List of Figures

Figure 1.1: Thesis structure 8
Figure 2.1: A model of the urban economy that relates productivity to transport investments via effects on city size 20
Figure 2.2: A schematic model of the theoretical linkages between transport investments and agglomeration economies.....22
Figure 2.3: Synthesis of values of elasticities between productivity and transport infrastructure provision – previous studies.....67
Figure 3.1: Research methodology 72
Figure 4.1: Location of Melbourne CBD 85
Figure 4.2: Boundary of Melbourne CBD 86
Figure 4.3: Distribution of employment across industries within the CBD.....87
Figure 4.4: Composition of occupation type across employment within the CBD 88
Figure 4.5: Distribution of Managers and Professionals across industries in the CBD 89
Figure 4.6: Employment growth across industries in the CBD from 1992 – 2006 90
Figure 4.7: Employment growth of Melbourne CBD and surrounding SLAs from 1992 – 2006 91
Figure 4.8: Profile of the total no. of train services entering the CBD on a weekday..93
Figure 4.9: Purpose of trips into Melbourne CBD.....94
Figure 4.10: Mode share of CBD work trips on weekdays.....95
Figure 4.11: Distribution of rail work trips into CBD in AM peak based on distance of origin from the CBD 95
Figure 4.12: Melbourne metropolitan train patronage (FY1945-46 to FY2006-07).....96
Figure 4.13: Growth predictions in the daily public transport patronage up to 2036...97
Figure 4.14: Car ownership level of CBD employees who takes the rail to work in AM peak hour 98
Figure 4.15: Level of public transport supply for the various Local Government Areas 100
Figure 4.16: AM peak rail congestion level facing Melbourne CBD (FY2004-05 to FY2014-15) 107
Figure 4.17: Travel intensity of work journeys in city centres.....110
Figure 4.18: Employment densities and journey-to-work mode share for Sydney's key employment centres 110

List of Figures

Figure 5.1: Research focus of Chapter Five 118
Figure 5.2: Overview of the MITM modelling framework 120
Figure 5.3: MITM simulation process and outcome 124
Figure 5.4: Mode split structure in MITM 129
Figure 5.5: Alternative choices for work trips in the absence of transit 134
Figure 5.6: Possible trip reaction and impact in circumstances of rail capacity constraint 143
Figure 5.7: Proportion of car trips entering the CBD from various distant bands under different scenarios of rail capacity constraint in AM peak 146
Figure 6.1: Research focus of Chapter Six 164
Figure 6.2: Melbourne CBD employer survey methodology 166
Figure 6.3: Percentage of companies (based on total employment) in each sector who are prepared to increase remuneration to attract or retain staff 171
Figure 6.4: Composition of occupation types for various sectors within the CBD 172
Figure 6.5: Percentage increase in annual remuneration that each sector is willing to pay for 10% and 30% rail capacity constraint 173
Figure 6.6: Percentage of companies (based on total employment) in each sector which indicate that rising congestion may have a detrimental impact on their short term (1-2 years) employment plans 175
Figure 6.7: Percentage change in total annual employment for each sector under 10% and 30% rail capacity constraint 177
Figure 6.8: Percentage of companies in each sector which are prepared to consider relocating out of the CBD in the longer term should traffic congestion increases 178
Figure 6.9: Targeted and actual participation rate 181
Figure 6.10: Size distribution of CBD firms (in terms of employment) based on CLUE data and actual survey participation 181
Figure 6.11: Employment suppression impact associated with a 10% rail capacity constraint estimated from survey and MITM output – short term 185
Figure 7.1: Research focus of Chapter Seven 191
Figure 7.2: Comparison between the CBDs of Australian and other international cities 199
Figure 7.3: Plot of CBD's GRP and daily rail capacity provision against total CBD employment 201

List of Figures

Figure 7.4: Plot of total CBD employment against CBD GRP for the 20 cities.....208
Figure 7.5: Sensitivity analysis – total CBD employment against CBD GRP 210
Figure 7.6: Employment suppression impact associated with a 10% rail capacity constraint (AM peak) estimated via different approaches – short term.....213
Figure 8.1: Research focus of Chapter Eight 222
Figure 8.2: Overview of the TERM modelling framework 225
Figure 8.3: Full dimension multiregional CGE model database.....228
Figure 8.4: TERM's comparative-static interpretation of results 239
Figure 8.5: Labour supply and demand curves for Inner Melbourne region.....252
Figure 8.6: Productivity deterioration effect on labour market movement in short and long term in a 2-region economy 259
Figure 8.7: Economic impacts associated with a 10% rail capacity constraint – expressed as a percentage change in Inner Melbourne region's GRP.....268
Figure 8.8: Percentage shares of job losses across the sectors in Inner Melbourne region for the short and long-run.....287
Figure 9.1: Research focus of Chapter Nine 291
Figure 9.2: Estimation framework for agglomeration dis-benefits based employment suppression impact measure.....298
Figure 9.3: Summary of findings based on employment suppression impact measure 305
Figure 10.1: Research focus of Chapter Ten and summary of agglomeration dis-benefit estimates from various approaches 307
Figure 10.2: Comparative assessment of the potential SR agglomeration dis-benefits (per annum) associated with a 10% rail capacity constraint in AM peak 308
Figure 10.3: Comparative assessment of the potential LR agglomeration dis-benefit (per annum) associated with a 10% rail capacity constraint in AM peak 312
Figure 10.4: Comparative assessment of the potential LR agglomeration dis-benefits (direct effects) on Melbourne CBD.....314
Figure 10.5: Comparative assessment of the potential LR agglomeration dis-benefits (net effects) on Melbourne CBD 316

List of Figures

Figure A1: AM peak rail capacity provision form FY2004-05 to FY2014-15.....336
Figure A2: AM peak rail demand from FY2004-05 to FY2014-15.....338
Figure A3: AM peak rail congestion facing Melbourne CBD.....339
Figure C1: Melbourne CBD employer survey methodology.....348
Figure C2: Targeted and actual participation rate 355
Figure D1: Rail network serving City of Toronto.....380

List of Tables

Table 2.1: Strengths and weaknesses of the four methods to estimate wider economic benefits....30
Table 2.2: Comparative assessment of international urban rail project evaluation approaches....33
Table 2.3: Output elasticities derived from aggregate production functions (based on time series data)....40
Table 2.4: Synthesis of studies that found a positive link between public infrastructure provision and productivity....42
Table 2.5: Synthesis of studies that found a weak link between public infrastructure provision and productivity....46
Table 2.6: Synthesis of studies that considered both the effects of agglomeration and public infrastructure provision and productivity....50
Table 2.7: Synthesis of studies that made use of spatial data and density measure to estimate agglomeration economies....58
Table 4.1: Total journey-to-work trips from Melbourne metropolitan area to Melbourne CBD and corresponding public transport share....111
Table 4.2: Comparative assessment of 5 major Australian CBDs (2006)....114
Table 5.1: Trip purposes in MITM....123
Table 5.2: Impacts of public transport strikes....132
Table 5.3: Demographics and vehicle population of Wisconsin State and Victoria State (2006)....133
Table 5.4: Results of travel behaviour surveys from TPMS and Volusia County Public Transit....135
Table 5.5: The potential trip suppression impact for various trip purposes if public transport was withdrawn....136
Table 5.6: Equations to estimate the probabilities of affected CBD auto users to shift to other alternatives....141
Table 5.7: Variable descriptions....141
Table 5.8: Alternative choices for work-related automobile trips when rail capacity is constrained – adjusted from HLB (2003)....142
Table 5.9: MITM output – the average generalised cost of automobile trips for Base Case (2006) and various levels of rail capacity constraint....147

List of Tables

Table 5.10: MITM output – the percentage increase in average generalised cost of automobile trips under various levels rail capacity constraint compared to Base Case 149
Table 5.11: MITM output – the average travel times of automobile trips for each level of rail capacity constraint (minutes) 150
Table 5.12: Estimated number of AM work-related rail trips that may be cancelled for various levels of rail capacity constraint (passenger trips) 154
Table 5.13: Estimated number of AM work-related automobile trips that may be cancelled for various levels of rail capacity constraint (automobile trips) .. 156
Table 5.14: The estimated CBD employment suppression impact due to cancellation of automobile trips (number of employees) 157
Table 5.15: Total amount of employment estimated to be suppressed for various levels of rail capacity constraint – short and long term effects 158
Table 5.16: Share of employment estimated to be suppressed for various levels of rail capacity constraint – short and long term effects 158
Table 6.1: Summary of key survey results 170
Table 7.1: Cities selected for analysis 193
Table 7.2: Summary of CBD employment size, GRP and daily rail provision of international and Australian cities 198
Table 7.3: Variable descriptions 202
Table 7.4: Results of stepwise regression with LnGRP as dependent variable – output from SPSS 205
Table 7.5: Results of linear regression with LnTotEmploymt as dependent variable – output from SPSS 211
Table 7.6: Results of linear regression with LnGRP as dependent variable – output from SPSS 214
Table 8.1: Generic equations that define the sourcing mechanism in TERM 232
Table 8.2: Variable descriptions 233
Table 8.3: Sets and set elements 233
Table 8.4: Employment distribution across industries for CBD and Inner Melbourne region – TERM model database versus ABS data 242
Table 8.5: Proportion of each region's total labour income from the various regions of employment 245
Table 8.6: Ownership of capital stocks among regions 246

List of Tables

Table 8.7: Proportion of each region's total capital rental income from the various regions of capital consumption 246
Table 8.8: Proportion of each region's total land rental income from the various regions in which land is located.....247
Table 8.9: Income shares of each primary factor 248
Table 8.10: Equations that define investment and capital in each region in TERM....250
Table 8.11: Variable descriptions.....250
Table 8.12: Weighted average agglomeration elasticity value for Melbourne CBD....262
Table 8.13: Weighted average generalised cost of CBD trips (AM peak) for Base Case and Option scenario (i.e. a 10% rail capacity constraint) – based on TERM output 263
Table 8.14: Productivity shocks (associated with a 10% rail capacity constraint) for Melbourne CBD.....265
Table 8.15: Macro results from TERM for a short-run productivity shock of 0.09% on Inner Melbourne region – shown as a percentage change in variable.....269
Table 8.16: Estimation of inter-regional flow-on effects in the short-run for productivity shock of 0.09% - output from TERM.....275
Table 8.17: Possible employment lost from each sector within Inner Melbourne region for short-run productivity shock of 0.09% - output from TERM.....276
Table 8.18: Macro results from TERM for a long-run productivity shock of 0.09% on Inner Melbourne region – shown as a percentage change in variable.....279
Table 8.19: Proportion of intermediate goods and services consumed in region r that are purchased from region d.....283
Table 8.20: Percentage changes in the basic price of commodities in each region...283
Table 8.21: Proportion of intermediate goods and services produced in region r and sold to region d.....284
Table 8.22: Estimation of inter-regional flow-on effects in the long-run for productivity shock of 0.09% - output from TERM.....285
Table 8.23: Possible employment lost from each sector within Inner Melbourne region for long-run productivity shock of 0.09% - output from TERM.....286
Table 9.1: Productivity loss associated with a 10% rail capacity constraint for Melbourne CBD.....293
Table 9.2: Employment and GRP estimates for Melbourne CBD – short and long term 293

List of Tables

Table 9.3: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short and long term – estimated using PETE 294
Table 9.4: Productivity elasticity for Melbourne CBD in short-run and long-run – based on outputs from TERM and MITM.....300
Table 9.5: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short and long term – based on MITM's outputs and elasticity of 0.12.....301
Table 9.6: : Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short and long term- based on survey findings 302
Table 9.7: : Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short and long term- based on secondary data analysis findings 303
Table B1: Overall rail capacity serving the various CBDs in AM peak (2006).....341
Table B2: Overall rail demand for the various CBDs in AM peak (2006) 342
Table B3: Rail loading factor for various Australian CBDs (2006) 344
Table C1: Targeted participation rate across sectors 350
Table C2: Short term employment impacts across sectors 354
Table C3: Remuneration impacts across sectors.....358
Table C4: Magnitude of remuneration impacts across sectors.....360
Table C5: Short term employment impacts across sectors 361
Table C6: Magnitude of employment impacts across sectors.....363
Table C7: Number of companies across sectors that may relocate out of CBD in the longer term 364
Table D1: Details of the 20 cities 382
Table E1: Core equations of the TERM model.....391
Table E2: Variable descriptions 396
Table E3: Sets and set elements 398
Table F1: BOTE analysis (+2.09% wage shock).....400
Table F2: BOTE analysis (-1% aprim shock) 401
Table G1: Details of agglomeration elasticity 403
Table G2: Computation of a weighted average agglomeration elasticity – example based on values from DfT (2009) 404
Table G3: Weighted average agglomeration elasticity 404

List of Tables

Table G4: Weighted average generalised cost of travel into CBD (AM peak) for Base Case and Option scenario (i.e. a 10% rail capacity constraint) – based on MITM output 406
Table G5: Productivity shocks (associated with a 10% rail capacity constraint) for Melbourne CBD 408

Abstract

In recent years, the potential to produce economic benefits has become increasingly important to the decision-making process for urban passenger rail investments. Such benefits are seen as a motivation for rail investment either by encouraging jobs to locate in a particular location or by opening up new journey-to-work opportunities for residential areas. However, while a significant portion of the benefits (e.g. travel time savings) are already well captured under the present Cost-Benefit Analysis (CBA) methodology, the current conventional frameworks do not take into consideration other potentially significant impacts such as agglomeration benefits in production.

Agglomeration benefits in production are positive impacts on productivity amongst firms due to an increasing concentration of firms or increasing concentration of employment or widening of labour markets. A synthesis of evidence from previous studies suggests that agglomeration effects associated with urban rail projects might be significant. However, the wide range of estimated elasticity values clearly indicates that there is a knowledge gap pertaining to the plausible range of its economic value and the methodology to estimate such effects associated with urban rail.

The focus of this research is to explore the economic impacts of agglomeration economies for urban rail projects. The research uses a framework of survey and secondary research as well as an experimental modelling approach involving transport modelling and economic Computable General Equilibrium (CGE) modelling. The Central Business District (CBD) of Melbourne City is adopted as the case study in this thesis to explore and estimate such agglomeration effects associated with urban rail.

The fundamental assumption underlying the research methodology is that the urban passenger rail system serving Melbourne CBD is an enabler of the CBD's economic growth. Therefore, if urban rail capacity is constrained (i.e. rail demand exceeds rail capacity provision), agglomeration diseconomies due to the corresponding increase in traffic congestion would set in. The poorer accessibility of the CBD may impact upon the CBD's employment size and hence its productivity. The economic value of this urban dis-agglomeration will provide a mirror indication of the agglomeration benefits associated with the expansion of urban passenger rail provision. A major motivation for this approach is the overcrowding of Melbourne CBD rail services which has occurred over the last 5 years.

Two measures of agglomeration economies in urban rail were explored in this research - the potential CBD employment suppression impact and the reduction in the proximity between CBD firms and workers due to an urban rail capacity constraint. This research estimated the potential CBD employment suppression impacts using three different approaches - outputs from the transport modelling with trip elasticities, findings from a CBD employer survey and outputs from secondary data analysis. Productivity elasticities (from secondary research) were applied on the employment suppression impacts to estimate the agglomeration dis-benefits associated with an urban rail constraint.

The deterioration in the CBD's accessibility (i.e. the 2nd measure of agglomeration economies used in this research) has also been employed to estimate the agglomeration dis-benefits and to derive a range of productivity shocks, using the method adopted by the UK and New Zealand to estimate agglomeration benefits. The productivity shocks were then inputted into a CGE model to estimate its impact on Melbourne CBD's economy. A comparative assessment of the agglomeration estimates from the various approaches was carried out and the results presented in this thesis.

This research provides an important contribution to knowledge by exploring a range of alternative methods to estimate agglomeration economies in urban rail and compares the results of these with the conventional method to understand the robustness and variability of outcomes. To the best knowledge of the author, no other published research has undertaken a comparative assessment of this kind. In particular, no previous published study has explored agglomeration economies associated with urban rail using CGE models in this manner. The main contribution of the CGE modelling work includes the development of the modelling approach for agglomeration economies in urban rail and the demonstration of how such agglomeration economies may impact Melbourne CBD and other regions in the short and long term. This finding contributes to the understanding of the overall effect of agglomeration economies in urban rail which is beneficial in the appraisal of future rail proposals. In addition, this understanding is also valuable as it can help eradicate the double-counting ambiguity regarding agglomeration benefits.

Author's Declaration

This thesis contains no material which has been accepted for the reward of any other degree or diploma in any other university or institution. The author affirms, to the best of his knowledge, that this thesis contains no material previously published or written by any other person, except where due reference is made in the text.

Tat Meng Gwee
November 2010

Acknowledgements

This PhD marathon has been an amazing journey which is made more challenging by an ambitious inter-disciplinary research methodology – who would have expected a research student from the Institute of Transport Studies (ITS), Civil Engineering department to use an economy-wide CGE model as part of his research. Completion of this mammoth task has been made possible with the support and guidance from a group of very special people who shared this journey with me.

Firstly, I would like to thank my better half for her unfailing love, companionship and encouragement. She sacrificed her career and more for me to pursue my PhD dream. Throughout this journey, she has been my pillar of strength, without which I would have given up long time ago. I would also like to thank my wider family for their encouragement and support all these years, in particular, my mother-in-law who had been flying into Melbourne every few months to visit us.

I owe an eternal knowledge debt to my three supervisors – Professors Graham Currie, John Stanley and John Madden. I would like to express my deepest gratitude to my main supervisor, Professor Currie, for his encouragement and academic guidance throughout my candidature. I am also grateful to Professor Stanley for his tutelage especially in the area of economics. The execution of this ambitious research program would have been more challenging without their constant motivation and good supervision. I would also like to thank Professor Madden (from the Centre of Policy Studies (CoPs)) for his patience and supervision in my use of the TERM model. The application of TERM in this research would have been more difficult without his generous guidance.

I am also thankful to Professors Peter Dixon and Maureen Rimmer from CoPs for their guidance during the brief absence of Professor Madden. Special thanks also go to Ms Alexa Delbosc (research fellow, ITS) for her advice in the use of SurveyMonkey and SPSS. I would also like to thank the staff of ITS and the Civil Engineering department, in particular, Ms Jennifer Mason for all the administrative assistance. I am also grateful to my employer, the Land Transport Authority (Singapore) for sponsoring my doctoral programme. In particular, I would like to thank Mr Low Tien Sio, Ms Eng Sok Yong and Ms Lina Lim for believing in me and supporting my scholarship.

Last but not least, I would like to thank the Lord for bringing me this far in my life. I am ashamed to confess that in the darkest moments of this journey, there are times when my belief is shaken. But I am thankful that He has never given up on me. The completion of this PhD is my personal testimony to Hebrew 13:6:

"The Lord is my Helper and I will not fear what man shall do unto me!"

Praise the Lord and God bless.

Copyright Notices

Notice 1

Under the Copyright Act 1968, this thesis must be used only under the normal conditions of scholarly fair dealing. In particular no results or conclusions should be extracted from it, nor should it be copied or closely paraphrased in whole or in part without the written consent of the author. Proper written acknowledgement should be made for any assistance obtained from this thesis.

Notice 2

I certify that I have made all reasonable efforts to secure copyright permissions for third-party content included in this thesis and have not knowingly added copyright content to my work without the owner's permission.

Chapter 1
Introduction

1.1 Background and Motivation

In recent years, the potential to produce economic benefits has become increasingly important to the decision-making process for urban passenger rail investments (Transportation Research Board (TRB), 1998, Keegan et al., 2007). Such benefits are seen as a motivation for rail investment either by encouraging jobs to locate in a particular location or by opening up new journey-to-work opportunities for residential areas (Nash, 1992). However, while a significant portion of the benefits (such as travel time savings) are already well captured under the present Cost-Benefit Analysis (CBA) methodology, current conventional evaluation frameworks do not take into consideration other potentially significant impacts such as the benefits to a region's economy generated by transport infrastructure (Vickerman, 2007b, Eddington, 2006b, Graham, 2006a). Such benefits are commonly known as wider economic benefits (Vickerman, 2007a, TRB, 1998).

Recent studies such as Graham (2007a), Eddington (2006a) and Department for Transport (DfT) (2006) suggest that, of the wider economic benefits associated with transport projects, agglomeration benefits are likely to be significant. Agglomeration benefits are positive impacts on productivity amongst firms due to an increasing concentration of firms or employment or wider labour markets (DfT, 2006). According to Keegan et al. (2007), agglomeration benefits for public transport projects is a new field where no significant research had been carried out until the recent works of Graham (2005, 2006a, 2006b). TRB (1996, page 25) also indicated that "there have been relatively few comprehensive, integrated analyses of the long-term, region-wide economic impacts of increased transit investment and use". A survey of international CBA practices (for urban rail projects) also showed that few countries have incorporated agglomeration benefits (to some extent) in their current CBA framework (Gwee et al., 2008).

A review of earlier studies that have been carried out in this field showed conflicting findings. Most studies have argued that transport is crucial in sustaining cities and supporting urban agglomerations; these in turn can generate external benefits to the economy which are presently not included in standard appraisals for transport investment (e.g. Vickerman, 2008a, Graham, 2007b). On the other hand, there are several other authors who are sceptical about these impacts (e.g. Hall and Hass-Klau, 1985, Haughwout, 1999).

The methodology employed in earlier studies (e.g. Aschauer, 1989, Munnell, 1990, Seitz, 1995) largely involved the use of Production Function techniques with comprehensive time-series or cross-sectional data on productivity, employment and public capital stock. However, the output from such studies in the form of an elasticity between productivity gains with respect to the highly aggregate infrastructure investment varies widely and no distinction is made between the direct and indirect effects (European Conference of Ministers of Transport, 2001). In addition, the productivity gains estimated from these elasticities may not be totally attributable to agglomeration effects. While later studies by Graham (2005, 2006a, 2006b) derived agglomeration elasticity[1] values specifically for measuring such wider economic benefits, the data were based on the UK context. There is therefore a clear case to improve the methodology for estimating agglomeration benefits.

The focus of this thesis is therefore to explore the economic impacts of agglomeration economies specifically for urban rail projects. The research uses a framework of primary survey and secondary research as well as an experimental modelling approach involving transport modelling and economic Computable General Equilibrium (CGE) modelling. The Central Business District (CBD) of Melbourne City is adopted as the case study in this thesis to explore and estimate such agglomeration effects.

[1] Agglomeration elasticity derived by Graham (2005, 2006a, 2006b) refers to an elasticity between the productivity of a region with respect to an agglomeration metric that measures the accessibility of workers to firms, developed by Graham to model agglomeration economies. Further explanation of this elasticity is provided in Chapter Two – Section 2.6.4.

1.2 Research Aim and Objectives

The broad aim of this research is to better understand the agglomeration economies specifically associated with urban passenger rail projects. Consistent with this goal, the following two objectives have been established for this research.

i. To develop a better understanding of the impacts of an urban rail capacity constraint (i.e. a situation where rail demand exceeds rail capacity provision) on employment and productivity, using a comprehensive framework of transport modelling, secondary research and data analysis as well as a primary survey of CBD employers.

ii. To assess and compare the economic value of these productivity impacts due to agglomeration effects estimated using different approaches.

1.3 Scope of Study

The aforementioned study objectives define the research agenda. In line with this agenda, the research scope of this thesis includes the following.

- The focus of the research is urban passenger rail systems. This refers strictly to urban electric mass transit systems that are operated totally independent from other traffic and which provide high frequency services between the CBD or central city and the other parts of the metropolitan area. This research does not examine suburban or regional passenger rail networks.

- In this research, Melbourne CBD is selected as the case study to explore the agglomeration effects of urban passenger rail. Agglomeration benefits associated with urban passenger rail are envisaged to be most evident in the CBD given its high urban development intensity and heavy dependence on the urban rail system for accessibility.

- The research examines only the morning (7 – 9 AM) peak period of a typical weekday as the assessment period, since the majority of CBD employees make their journey-to-work trip at this time and hence agglomeration benefits are expected to be most substantial. The corresponding effects attributable to the presence of rail during the off-peak or evening peak time period are not envisaged to be substantial.

- The research framework includes an experimental modelling approach involving the use of transport modelling and CGE modelling. As part of the approach, a range of rail congestion scenarios which affect the accessibility[2] of Melbourne CBD in the AM peak are tested using an existing operational transport model.

- The study estimates the agglomeration effects associated with an urban rail capacity constraint serving Melbourne CBD using the following two measures:
  1. The potential CBD employment suppression impact
  2. The potential change in the proximity between CBD firms and workers.

  The 1st measure is estimated using different approaches including outputs from transport modelling with trip elasticities, primary surveys and secondary data analysis. The 2nd measure is estimated using the approach that the UK and New Zealand adopt to estimate agglomeration benefits. This is referred to as the **PETE** method in this thesis as it essentially measures the change in **P**roximity between **E**mployees **T**o **E**mployers.

- Productivity elasticities[3] from secondary research and data analysis are applied on the employment suppression impacts (from 1st measure) to estimate their associated agglomeration diseconomies. An existing operational CGE model is used to estimate the economic value of the associated productivity loss estimated using the 2nd measure. This research compares the agglomeration diseconomies estimated using these various approaches.

The modelling work conducted in this research made use of existing transport and CGE modelling platforms. The modelling work does not concentrate on the accuracy of the modelling system itself. While the transport modelling framework does not involve the enhancement to the existing model nor development of a new modelling methodology, modifications within the possible scope of this research are introduced to the CGE model to facilitate the particular transport application reported in this thesis.

[2] Accessibility refers to the ease with which people can access services and activities in an area. It is measured in terms of generalised transport costs (Litman, 2008a).

[3] Productivity elasticity refers to the elasticity between productivity gains and urban size / employment concentration (i.e. the number of workers per unit area). See Section 2.6.4 for mode information.

1.4 Research Contributions

A summary of the major contributions of this research to knowledge are as follows.

1. The Use of Alternative Methods to Estimate Agglomeration Economies

This research provides contribution to knowledge by exploring a range of alternative methods to estimate agglomeration economies using:

- travel demand elasticities (Chapter 5)
- primary data collection (Chapter 6)
- aggregate city wide secondary data analysis (Chapter 7).

To the best knowledge of the author, no previous published research has explored agglomeration economies in urban rail using the above approaches. In addition, the results of these approaches are compared with conventional methods to understand robustness and variability of outcomes (Chapter 10). No other published research has undertaken a comparative assessment of this kind.

2. Estimating Agglomeration Economies Using CGE Modelling

This research experimented with a CGE modelling approach to estimate agglomeration economies (Chapter 8). No previous published research has explored agglomeration economies in CGE models in this manner. The major contribution of the CGE modelling work includes the development of the modelling approach for agglomeration economies and the use of the CGE model to demonstrate how the agglomeration economies in the urban rail serving Melbourne CBD may impact other regions in the short and long term – this thesis defines a short term as a period between 1-3 years and a long term as a period longer than that; this is to be consistent with the CGE modelling timescale assumption[4].

[4] The short and long term timescales are not explicitly defined in CGE modelling (Horridge, 2003, page 58). Dixon et al. (1982, page 65) explains that the simulation timescale is generally considered as the period of time that would be needed for economic variables to adjust to a new equilibrium. Horridge (2003, page 58) suggests that "a short-run is usually thought to be between 1 and 3 years" and a long-run is a period longer than that. This thesis adopts this timescale assumption so as to be consistent with the CGE modelling context. See Chapter 8 (Section 8.5.2) for more details about the timescale assumption.

3. Agglomeration Diseconomies

The focus of the research case study has been on examining agglomeration diseconomies resulting from rail congestion. There is no previous research in the transport field that considered diseconomies related to agglomeration effects. The exploration of this issue in this research is new and hence represents a new contribution to knowledge.

4. Links between Rail and Agglomeration Economies

The focus of the research has been agglomeration economies associated with CBD access by rail. A contribution of the research has been to elaborate the important impact of rail access in relation to agglomeration economies in CBDs.

1.5 Thesis Structure

This dissertation comprises eleven chapters of which this is the first. The thesis structure is shown in Figure 1.1.

Chapter Two: Literature Review presents the theory on agglomeration economies and surveys past literature on the relationship between transport infrastructure, productivity and agglomeration economies. This chapter also highlights the knowledge gaps in this field.

Chapter Three: Research Methodology presents the research methodology adopted in this study. The proposed study approach consists of five main components: transport modelling, secondary data analysis and research, Melbourne CBD employer survey, CGE modelling and comparative assessment of results.

Chapter Four: Case Study: Travel Issues to Melbourne CBD discusses the travel issues pertaining to Melbourne CBD so as to provide a consolidated understanding of the rail utilisation and congestion issues facing CBD employees. This is to set the stage for the subsequent chapters of the thesis which present the findings of the various components of the research framework.

Chapter Five: MITM Modelling introduces the Melbourne Multi-modal Integrated Transport Model (MITM), which was used in this research to investigate how travel into Melbourne CBD in the AM peak will change under a different level of rail congestion. The modelling output from MITM has been used as an input to estimate the potential CBD labour supply suppression impact associated with a rail capacity constraint. The estimates of the employment suppression impacts are also presented in this chapter.

Chapter Six: Melbourne CBD Employer Survey reports the findings of the Melbourne CBD employer survey which was conducted to gather information from CBD employers regarding the potential impact that rail congestion may have on their businesses in particular their labour demands.

Chapter Seven: Secondary Data Analysis presents the analysis of data from international and Australian cities to explore the relationship between CBD employment and productivity and urban rail capacity provision.

Chapter Eight: TERM Modelling introduces the CGE model – The Enormous Regional Model[5] (TERM) – which was used in this research and reports its output on the economic value of productivity impacts associated with urban rail constraints.

Chapter Nine: Agglomeration Estimates - Approach reports the method and outcome of computing agglomeration diseconomies associated with an urban rail capacity constraint using different approaches.

Chapter Ten: Agglomeration Estimates – Comparative Assessment compares the agglomeration diseconomies estimated using the different approaches presented in Chapter 9. This is to understand the merits of the two measures of agglomeration adopted as well as to test the robustness and variability of alternative approaches

Chapter Eleven: Conclusions summarises the key findings and contributions of this research and suggests directions for future work.

[5] This is the name given to the CGE model by its creator in the Centre of Policy Studies, Monash University in order to highlight its capacity to handle many economic agents and many regions simultaneously (Horridge et al., 2005).

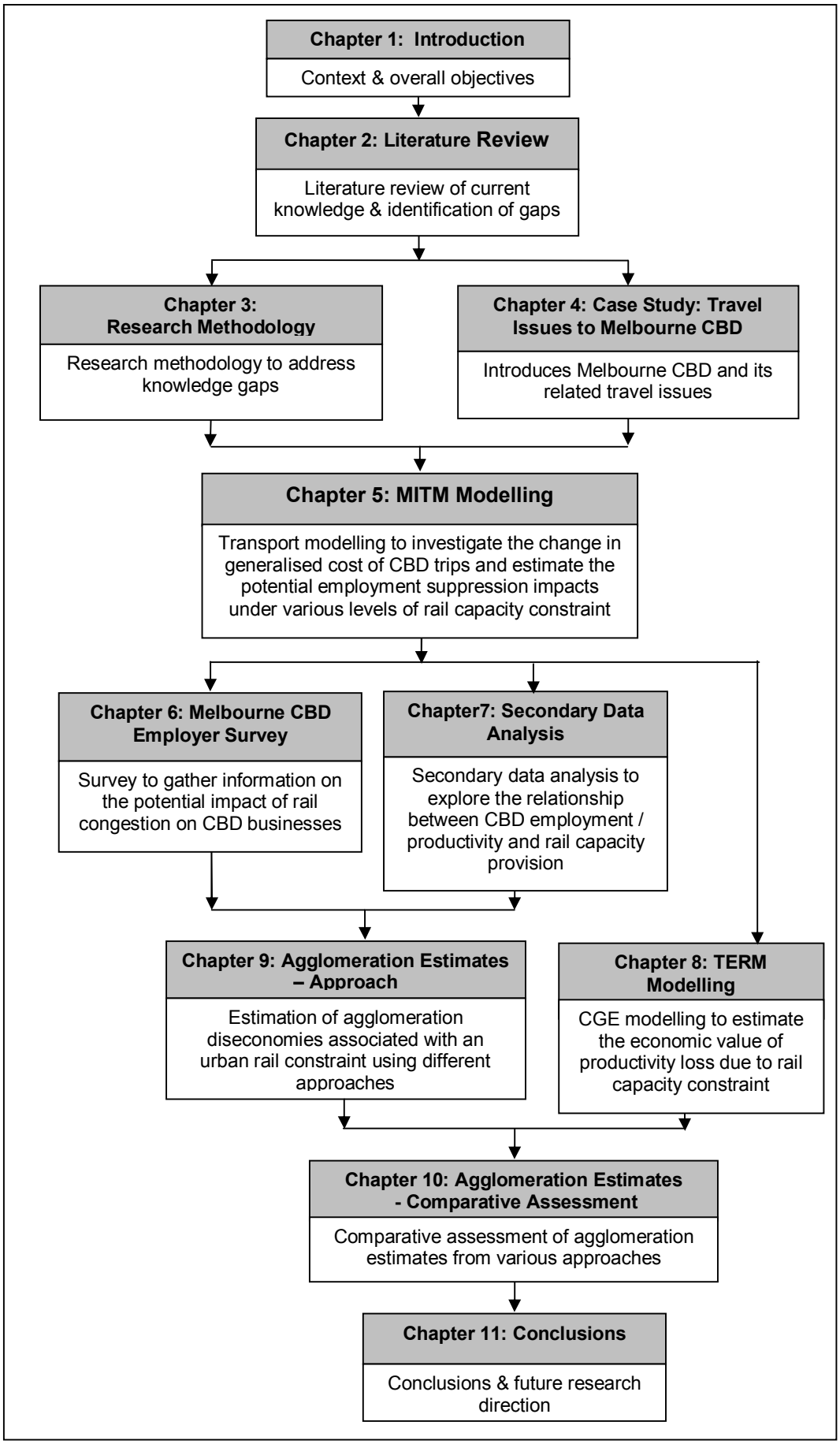


Figure 1.1: Thesis structure

CHAPTER 2

Literature Review

2.1 Introduction

The specific objectives of this chapter are:

1. to better understand the theory of agglomeration, in particular the agglomeration effects of transport projects
2. to identify knowledge gaps in this field.

This chapter is structured in the following order.

- **Section 2.2 -** **Wider Economic Benefits in Transport Projects** introduces the various types of wider economic benefits associated with transport projects.
- **Section 2.3 -** **Theory of Agglomeration** presents the concept and ideas of agglomeration economies.
- **Section 2.4 -** **Agglomeration Effects of Transport Projects** discusses the mechanisms by which transport improvements could promote agglomeration economies.
- **Section 2.5 -** **Estimating Agglomeration Effects: Alternative Methodologies** outlines the various methodologies to estimate wider economic benefits.
- **Section 2.6 -** **A Review of Past Studies** reviews previous studies in this field.
- **Section 2.7 -** **Synthesis and Knowledge Gaps** synthesises the findings of the literature review and highlights the knowledge gaps in this field.
- **Section 2.8 -** **Summary** concludes the chapter.

2.2 Wider Economic Benefits in Transport Projects

According to the UK Department for Transport (DfT) (2006), transport schemes may bring about four effects to a region's economy which are not captured in the current transport appraisal framework. These four types of wider economic effects are described briefly as follows.

1. Business time saving effects – faster and more reliable journeys in the course of work represent a productivity gain.

2. Competition effects – transport improvement can help to improve a region's competitiveness and thus bring about a Gross Regional Product (GRP) impact. In addition, the presence of imperfect competition means that the value of travel time savings in the conventional appraisal framework is underestimated.

3. Labour Market effects – improvement in transport facilities may encourage more people to be willing to enter the labour market, to be willing to work longer hours and employment could be relocated from a lower productivity area to a higher productivity area; overall, these effects in the labour market will impact on GRP.

4. Agglomeration effects – agglomeration economies occur when output per capita increases as a consequence of an increase in the absolute size or concentration of employment and population. It is claimed that by reducing the costs of distance, transport improvement increases effective density (even if there is no change in land use) and therefore increases overall economic output.

Recent studies such as Marshall and Webber (2007), Eddington (2006a), DfT (2006) and Graham (2005, 2006b) suggested that of the wider economic benefits associated with transport projects, agglomeration benefits are likely to be significant.

2.3 Theory of Agglomeration

The following section presents the theories pertaining to agglomeration economies.

2.3.1 Definition

Agglomeration benefits in production are the positive impacts on productivity amongst firms due to an increase in the absolute size or concentration of employment and population (DfT, 2006, New Zealand Transport Agency, 2008). In line with the focus of this research, Transportation Research Board (TRB) (1998) defined agglomeration economies in transit as the increase in productivity, creativity and synergy amongst firms because of a higher number or concentration of firms and employment made possible by more compact, transit-served development.

2.3.2 Drivers and Effects of Agglomeration

Various literature have cited that cities are the evidence of the natural forces of agglomeration (e.g. Jacobs, 1969 and Phelps, 2004). According to Marshall and Webber (2007) and Eddington (2006a), while cities are not cheap places to conduct our economic activities (as costs such as property prices and wages tend to be higher), firms are willing to locate in cities so as to enjoy a range of productivity benefits that more than offset the higher costs of city locations. As these authors note, economists call these benefits agglomeration economies. These sources of agglomeration economies were first postulated by Marshall (1920).

Marshall (1920) identified three different types of benefits – the reduced costs of moving goods, people and ideas – that could be achieved by industrial agglomeration. Firstly, he argued that firms will locate near one another to reduce the delivery costs of getting inputs or transportation costs to downstream customers i.e. input sharing. Secondly, he developed a theory of labour market pooling in which firms locate near one another to share labour. Thirdly, Marshall (1920, page 225) introduced the concept of knowledge spillovers by arguing that in agglomerations, “the mysteries of the trade become no mystery, but are, as it were, in the air” and that “if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas”. He emphasised the advantages that accrue to firms when workers learn quickly from each other in an industrial cluster.

Following the work of Marshall (1920), many studies have suggested that agglomeration or clustering of economic activities would increase the innovation and competitiveness of industries (e.g. Jacobs, 1969, Porter, 1990 and Rosenthal and Strange, 2001). Simmie (2004) identified the following four key drivers of agglomeration.

1. Concentration of firms in the same input-output production and consumption hierarchy - this is termed the "pure agglomeration" type of local firm concentration.
2. Minimisation of transport costs - firms co-locate in particular areas in order to minimise their transport costs. This type of firm concentration is manifested in the traditional location of coalmines and power stations where the location of natural resources and their use are the driving forces of concentration. This is termed the "industrial complex" type of local firm concentration.
3. Social network relationships - firms also group together because of social network relationships where the trust relationship that exists between firms make them locate within "reasonable" proximity to one another so that they can act as a group in support of mutual goals.
4. Concept of knowledge spillover - as knowledge may decay with distance, firms tend to concentrate in particular locations so as to benefit from the locally produced knowledge which are spilled from other firms in the area.

Keegan at al. (2007) and Graham (2005) also explain that such increases in the concentration of economic activities may result in the outcomes reported below, which will increase the productivity of employment and hence bring about economic benefits.

- A larger, more skilled labour market which will provide employers with more choice of skills and more competition for jobs.
- A larger, more specialised client market which will create a more competitive business environment.
- A more competing and complementary business environment which will provide synergy and additional pressure for innovation and efficiency, which in turn will enable further specialisation amongst support services.
- A greater potential for interaction of knowledge, both formally through conferences and informally via social interaction which will enhance knowledge transfer.

2.3.3 Classification of Agglomeration Economies

Agglomeration economies are traditionally classified as (1) internal scale economies, (2) localisation economies and (3) urbanisation economies (Graham, 2005, Simmie, 2004). This classification of agglomeration economies was first developed by Hoover (1937, 1948).

2.3.3.1 Internal Scale Economies

Internal scale economies can arise within a firm as a consequence of the enlargement of the firm's scale of production at an existing site (Hoover, 1937). This expansion in production scale would lower a firm's unit cost of production (Eberts and McMillen, 1999) and hence generate efficiency gains (Graham, 2005). Carlino (1980) emphasised that increasing returns to scale is the "most important force" that gives rise to agglomeration economies.

Graham (2005) and Eberts and McMillen (1999) explain that internal scale economies are internal at the firm level as such economies are related to the size of the individual firm. They added that as a firm grows, it will be able to take advantage of specialisation in the division of labour as well as reduce cost of inputs through bulk acquisition and the more efficient use of specialised machinery.

Eberts and McMillen (1999) highlight that large-scale manufacturing establishments which lead to the formation of a "company town" (such as chocolate in Hershey or aircraft in Seattle) are good examples of industries with significant internal scale economies.

2.3.3.2 Localisation Economies

Localisation economies occur when a firm's unit costs are lower in an urban area that includes many firms in the same industry (Eberts and McMillen, 1999). Bergsman et al. (1972) explain that such economies arise from the close proximity of several firms engaging in the same activity; it is a key reason for the concentration of activities from specialist firms in certain areas. Bergsman et al. (1972) added that the study of localisation economies tells us little about why an activity started in the first place but may offer an explanation about why some activities are concentrated in certain places that offer similar advantages.

Graham (2005) explained that localisation economies describe the "efficiency gains generated through the increased scale of a particular industry operating in close spatial proximity" through the following three possible ways.

1. Ease of communication – which facilitates technological exchanges as well as access to specialised development facilities between firms within the same industry.
2. Higher efficiency in provision of intermediate goods – these inputs can be provided at greater variety and lower cost due to the growth of subsidiary trades and more favourable freight rates.
3. Larger markets for inputs and outputs – in particular the firms can share a larger local skilled labour pool.

Eberts and McMillen (1999) and Saxenian (1994) indicated that software firms in Silicon Valley is an obvious example of localisation economies, as the small typical firm size in the area suggested the absence of internal scale economies.

Carlino (1978) on the other hand argued that the spatial juxtaposition of firms in the same industry could result in localisation diseconomies (such as higher wages and rentals). He added that such localisation diseconomies are more likely to influence the locational decision of small firms because larger firms can "create their own scale of localisation economies internally". According to him, this suggested that the boundary of internal scale economies and localisation economies of large firms may not be clear. Having said so, studies have shown localisation economies to be generally intra-industry; they are external to firms but internal to the industry (Graham, 2005, Kloosterman and Lambregts, 2001, Carlino, 1978).

2.3.3.3 Urbanisation Economies

Rosenthal and Strange (2004, page 2124) defined urbanisation economies as "externalities that arise from the concentration of all economic activity or from city size itself". Kloosterman and Lambregts (2001) simply termed urbanisation economies as the benefits to firms "accruing from overall local urban scale and diversity".

Graham (2005), Kloosterman and Lambregts (2001) and Bergsman et al. (1972) explained that urbanisation economies describe the productive advantages that accrue to firms through the following two avenues.

1. The clustering of firms involved in similar industrial processes – the connection between these firms are the input-output flows where one firm serves as the supplier or customer of another or in some cases the two firms are linked because of their common relationship with a third.
2. The clustering of individual firms and industrial complexes in or near to large cities because of the characteristics of the city such as the primacy in communication media, good infrastructure and public service provision and the scale of markets.

Graham (2005) and Kloosterman and Lambregts (2001) have suggested that urbanisation economies are inter-industry; they are external to the firms and industry but internal within cities. Graham (2005, page 9), however, noted that the sources of urbanisation economies "have tended to be less well defined". While agreeing that urbanisation economies are "much harder to identify", Crampton and Evans (1992) argued that there must be some economic benefits to firms that are located in a large city in order to compensate for the higher cost of floor space and labour in the large city and these may take the form of closer proximity to customers.

Bergsman et al. (1972) argued that it is not easy to distinguish the various types of agglomeration economies in practice. They highlighted that in general, localisation economies tend to enhance the effect of urbanisation economies. Kloosterman and Lambergts (2001) highlighted that "empirical studies so far have provided conflicting results regarding the relative importance of localisation and urbanisation economies in urban and industrial development".

2.4 Agglomeration Effects of Transport Projects

Over the years, several studies have attempted to explain the agglomeration effects associated with transport investments and how these effects can lead to productivity growth. While agreeing that transport infrastructure does generate wider economic benefits, Nash and Preston (1991) highlighted that such benefits are complex and difficult to quantify. They argued that, for major transport projects, exclusion of such economic developmental benefits would have a significant effect on the result of the Cost-Benefit Analysis (CBA) which would work to the detriment of the project itself.

Graham (2006a) explained that the underlying concept of this phenomenon is that a higher concentration of economic activities within a certain geographical or travel time space would result in higher productivity; transport can influence that concentration of economic activities by improving their proximity or travel time to each other. This, he emphasised, will bring about travel time savings (which are already included in current CBA and other additional benefits generated by the improved productivity, which are presently not captured in economic appraisals.

The European Conference of Ministers of Transport (ECMT) (2001) noted that transport investments could promote agglomeration economies through the following mechanisms.

- Jobs & labour market - transport improvement may broaden the access of employers to a pool of qualified labour.
- Produce markets - transport investments may facilitate the expansion of market areas for goods and services which will increase competition and enhance innovation and efficiency.
- Unlocking land - new transport infrastructures may be required to provide access to new development sites which are presently constrained.

Studies by Litman (2004) also suggested that transit improvements can help to create land use patterns that increase regional productivity and economic development. He argued that while these wider economic benefits are difficult to measure, they are likely to be large.

More recently, DfT (2006), Eddington (2006b) and Vickerman (2007a) suggested that transport can influence the clustering of firms and businesses and impact the economy positively through the following five avenues.

1. Increases business efficiency through time savings and improved reliability for business travellers, freight and logistics operations which could enhance a company's productivity and on a larger scale, the country's GDP – Vickerman (2007a) highlighted that these benefits are in addition to those enjoyed by the users themselves.
2. Increases business investment and innovation by supporting economies of scale or new ways of working.
3. Supports concentration of economic activity by helping to expand labour market catchments, improve job matching and facilitate business to business interactions and knowledge transfer.
4. Improves the efficient functioning of labour markets through increasing the accessibility of jobs by facilitating geographic and employment mobility in response to economic activity (i.e. employment may relocate from a lower productivity area to a higher productivity area) as well as increase the willingness of people to enter the labour force and to work longer hours.
5. Increases competition amongst firms by providing better accessibility which will enable them to trade over a wider area; this will result in additional pressure for innovation, efficiency and synergy which would result in increasing returns to scale.

   (Vickerman, 2007a, DfT, 2006, Eddington, 2006b).

Several authors postulate that agglomeration benefits could add at least 25% additional benefits to CBA. Eddington (2006b, page 14) noted that a significant portion of the economic benefits (such as travel time savings) are already well captured under the current conventional CBA methodology. However, he argued that the existing appraisal framework does not take into consideration other potentially significant impacts on the economy and these missing wider economic effects (which include agglomeration benefits) could increase the overall project benefits 'by up to 50 per cent in some cases'.

Vickerman (2008b, page 1180) agreed that rail investment can bring about positive agglomeration impacts on productivity amongst firms due to an increasing concentration of firms or increasing concentration of employment and estimated that the wider economic benefits generated by rail projects 'may amount to as much as 55 per cent of the direct transport benefits'. Vickerman (2007b) further suggested that this increase in productivity due to the agglomeration effect could imply that the current CBA is underestimating the benefits associated with urban rail projects due to the following reasons.

- An increase in productivity (which should logically lead to an increase in wages) would imply that a higher value of time savings should be applied in CBA.
- An increase in productivity would also enable firms to produce the same output with fewer workers which imply that there would be additional time savings.

The work of Marshall and Webber (2007) also estimated that agglomeration effects in transport projects could add up to 25% to the economic benefits estimated using conventional appraisal methods.

To illustrate that there are additional benefits that arise from transport investment over and above those that are currently captured in conventional CBA, Venables (2004, 2007) developed a model of an urban economy that relates productivity to transport investment via effects on city size. Venables (2004, 2007) argued that the positive city size - productivity relationship suggests that an improvement in the transport facilities might enhance productivity by:

1. improving the links between firms within the city, thereby increasing the effective density of the cluster
2. relaxing the constraints on access to the city thereby increasing the overall city employment.

Venables (2004, 2007) emphasised that these benefits generated by the productivity-city size effect due to transport investment, are additional to those economic benefits that arise due to savings in commuting resources and they are presently not included in conventional economic appraisals.

An outline of Venables' model is given in Figure 2.1. Figure 2.1(a) shows an urban equilibrium where the size of the city is determined to be at point E, which represents the state where the wage gap between the city workers and non-city workers is entirely dissipated in the travel costs of the city worker who is most distant from the CBD.

Figure 2.2(b) illustrates the situation when a transport improvement is made and the commuting costs are shifted downwards. As a consequence, the city size expands to Point E*. The increase in the output of the urban economy is presented by the area B+C while the total change in commuting is C-A which, when combined with the change in output (B+C), yields a real income gain from the transport improvement of A+B. In other words, A+B essentially represents the net gain in benefits from the transport improvement that is currently captured in the conventional CBA.

In Figure 2.1(c), Venables (2004, 2007) considers that agglomeration benefits mean that increasing city size would increase its productivity and so the wage gap between the city and non-city workers can be represented by a concave curve that increases with city size. The equilibrium state is now represented by the intersection point of the commuting cost and the wage curves. As shown in Figure 2.1(c), the real income gain is now A+B+D; where D is the agglomeration benefits that are presently not included in the evaluation framework.

Venables (2007, page 187) suggested that the same forces which cause cities to exist – agglomeration effects – offer additional benefits that should be considered in the appraisal of urban transport proposals. He stressed that "estimating their exact size (of agglomeration benefits) remains the subject of future work, but to ignore them is surely to miss one of the benefits of urban transport improvements".

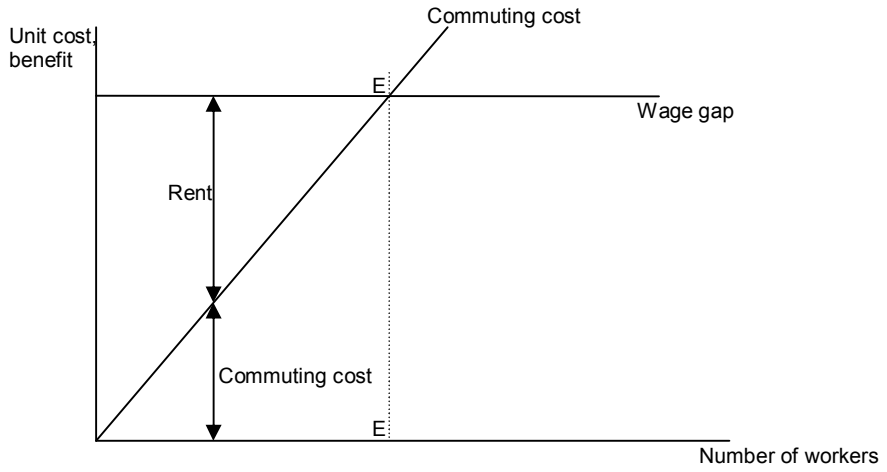


Figure 2.1 (a): Urban Equilibrium

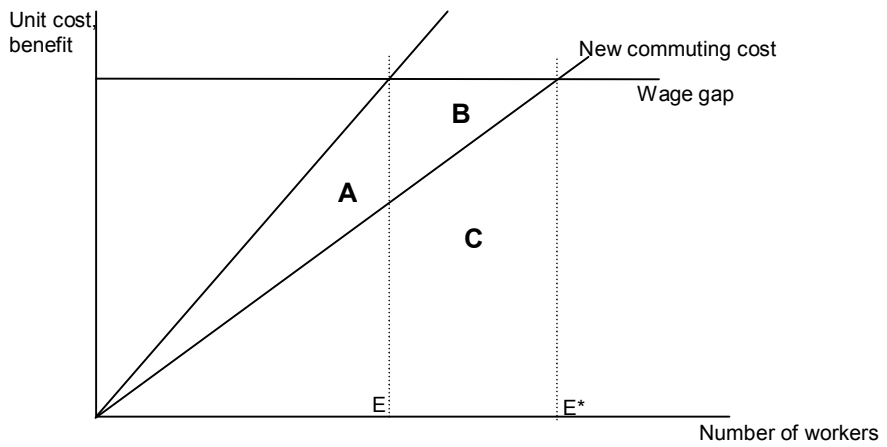


Figure 2.1 (b): Net gains from transport

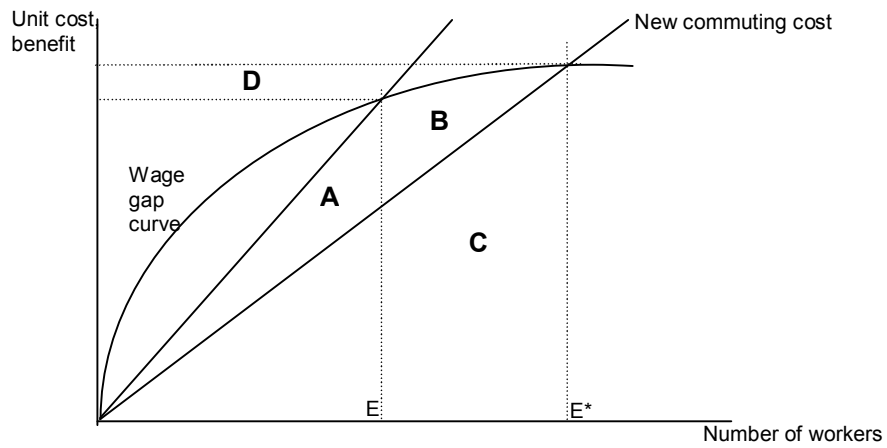


Figure 2.1 (c): Net gains from transport improvement with endogenous productivity

Source: Venables (2004, 2007)

Figure 2.1: A model of the urban economy that relates productivity to transport investments via effects on city size

2.4.1 Assessment

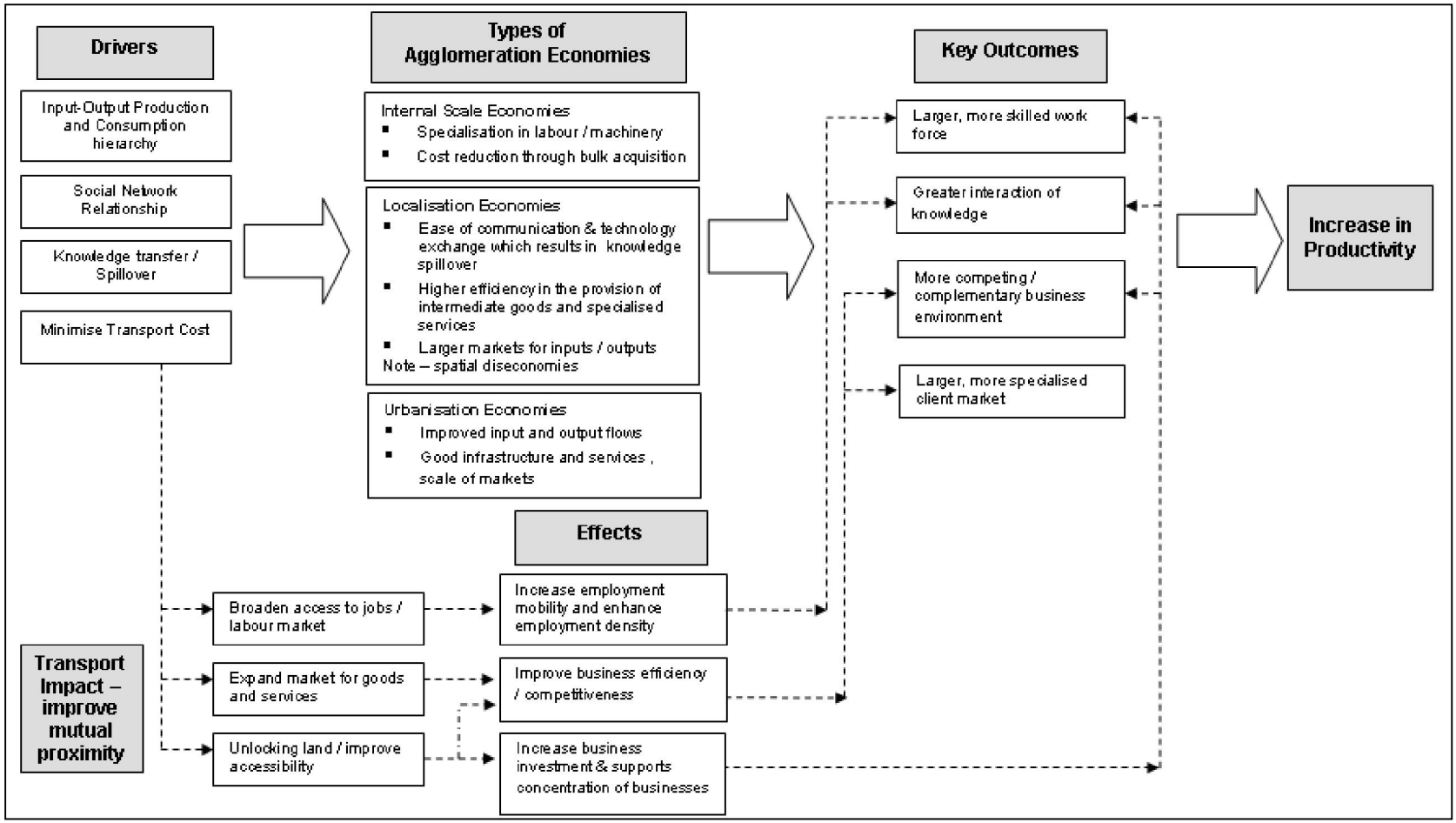
Figure 2.2 presents a schematic model of the theoretical linkages between transport investment and agglomeration economies developed as part of this research, based on literature review.

As shown in Figure 2.2, one of the key drivers of agglomeration is transport cost. The provision of a new transport infrastructure (such as urban passenger rail) or improvements to an existing transport network is expected to improve the mutual proximity between people and firms and reduce the generalised cost of travel. According to Graham (2005, 2006a, 2007b), this improved accessibility between people and jobs increases the effective density of employment[1] that is accessible to the firms. This may have the following three impacts.

1. Broaden access to jobs and labour market which would result in higher employment mobility and enhance employment density – this will create a larger, more specialised work force and also facilitate a greater exchange of knowledge amongst employees.
2. Expand market for goods and services which essentially means that firms will be able to trade over a larger area – this will result in a larger client market as well as create a more competitive and complementary business environment where firms would need to be more efficient and innovative and even collaborate so as to bring about higher returns to scale.
3. Improve accessibility to sites and unlocking land – the improved accessibility will improve business reliability and hence improve the firm's competitiveness. In addition, better accessibility will not only entice existing businesses to increase their investment on site, it will also attract new firms to set up their businesses in the area. This increase in concentration of businesses will help to expand labour market catchments and facilitate business to business interactions and knowledge transfer.

These positive effects brought about by transport improvements are expected to increase the individual firm's productivity which will collectively have an overall impact on the region's economy. Evidence from previous studies suggested that these agglomeration effects associated with transport investment might be substantial.

[1] Graham (2005, 2006a, 2007b) defined effective employment density of a location as the employment in and surrounding the area, weighted by their proximity to the location. See Equation 2.2 in Section 2.6.4 for more details.



Source: Developed from Bergsman et al. (1972), Carlino (1978, 1980), Kloosterman and Lambregts (2001), ECMT (2001), Simmie (2004), Graham (2005, 2006b, 2007b), Eddington (2006b) and Vickerman (2007a).

Figure 2.2: A schematic model of the theoretical linkages between transport investments and agglomeration economies

2.5 Estimating Agglomeration Effects – Alternative Methodologies

After examining the theories pertaining to agglomeration economies, this section presents alternative methodologies to estimate such effects. Literature review suggests that there are generally four broad theoretical methods to estimate the wider economic benefits associated with transport infrastructures. These methods include the following.

1. Comparative analysis
2. Surveys and interviews
3. Econometric estimation
4. Computable General Equilibrium (CGE) modelling.

The following section outlines the strength and weaknesses of each method. A comparative assessment of CBA approaches amongst 12 countries is also included in this section to illustrate the status of agglomeration benefits in international CBA framework and how different countries estimate their values.

2.5.1 Alternative Measurement Methodologies

2.5.1.1 Comparative Analysis

Comparative analysis provides a platform to learn from valuable experiences of similar projects in other countries or regions (Eijgenraam et al., 2000a). Such research is said to offer an indirect but valuable contribution to CBA as it can provide indications about the indirect effects of transport infrastructure such as the impact on land prices and other wider economic benefits. TRB (1998) argued that this approach also has the advantage of being relatively low-cost and easy to administer. In addition, this method also offers a powerful marketing tool for selling a transport proposal (such as a rail investment) to a wide range of audiences, as those unfamiliar with such projects can "gain a sense of comfort from reviewing real-world experience" (TRB, 1998, page 4-45).

While comparative analysis can be used to show the advantages of transit investments, it can often mislead decision-makers and the public into thinking that experiences elsewhere can be easily replicated in their communities (TRB, 1998). In addition, each community's experience with a transport initiative is unique in terms of physical, political, demographic and economic characteristic and hence one cannot assume that the experience of one community can be replicated elsewhere (TRB, 1998). To the best knowledge of the author, there is no published work to date that employed this method to measure agglomeration economies.

2.5.1.2 Surveys and Interviews

Surveys and interviews provide an easy and relatively inexpensive tool for predicting the direction and order of magnitude of the economic impacts of transit investments (Eijgenraam et al., 2000b, TRB, 1998). In particular, Gibbons and Overman (2009) suggested that collecting information about the productivity impacts of transport improvements from businesses may provide another useful approach to evaluate the associated wider economic impacts. In addition, this tool also serves as an avenue to provide information to the public about the transport proposal (TRB, 1998).

However, Gibbons and Overman (2009) argued that there are practical limitations to the scale and scope of such surveys and interviews and that very careful design is required to elicit useful and robust information from the participants. In addition, this method also has the following drawbacks.

- The direct and indirect effects associated with the transport proposals are not easy to distinguish in surveys and interviews.
- The information provided by the respondents is based on their opinions, perceptions and their individual interests in the project. They may therefore bias their response or their input may not always coincide with their actual behaviour, as they may not be familiar with the type of transport investment under consideration.
- The sample is often structurally distorted as the survey is often conducted among potential users, or more generally, among those directly involved. (Eijgenraam et al., 2000b, TRB, 1998).

To the best knowledge of the author, agglomeration economies have not been previously derived from the primary data collection approach.

2.5.1.3 Econometric Analysis

The third method, econometric analysis, is a frequently used statistical tool in the social sciences to test a hypothesis (TRB, 1998). In transport economics, economic analysis is used most typically to measure the generative impacts of transit investments and they are a widely recognised and accepted approach to isolate the impacts of transit investments (Eijgenraam et al., 2000b).

As highlighted by Graham (2005), econometric analysis via the application of Production Functions (PF) using regression models is the most common approach used in studies of agglomeration economies. The literature review presented in the next section bears testimony to this.

A PF is the relationship between the output (or productivity) attainable and the quantities of labour, capital and other input factors used to produce this output (McTaggart et al., 2007). In agglomeration analysis, it usually takes the following general form:

$$y_{ij} = g(z_j) f(L_{ij}, K_{ij}, G_{ij}) \qquad \text{(Equation 2.1)}$$

where

- y_{ij} is the output for the *ith* firm in the *jth* location
- $g(z_j)$ is a shift factor which represents agglomeration economies
- L_{ij} is labour input to firm *i*
- K_{ij} is capital input to firm *i*
- *Gij* represents other inputs which may be specified including energy, materials or public infrastructure;

  (Graham, 2005).

The shift factor, $g(z_j)$ represents agglomeration economies and is usually measured by either metropolitan employment or population to represent urbanisation economies or industry employment to represent localisation economies (Eberts and McMillen, 1999); recent work by Graham (2005, 2006b, 2007b) measured this as an effective employment density related to transport (i.e. the change in the accessibility between firms and employees).

Based on the literature review and information from Heathfield and Wibe (1987), econometric analysis using the PF approach can be generalised to the following four steps.

1. Collect data on the various parameters of interest for example output, labour, private capital stock and public infrastructure investment stock for the study area / region.
2. Fit a functional form of PF on the data.
3. Determine the suitability of the functional form by measure of "goodness-of-fit".
4. Derive a series of coefficients which will represent the output elasticities of the respective input factors by regressing the PF.

According to Heathfield and Wibe (1987), there are various functional forms of PF. As shown subsequently in Tables 2.4, 2.5, 2.6 and 2.7, the more popular functional forms include the Cobb Douglas[2] and Constant Elasticity of Substitution (CES)[3] functions that were largely used in earlier work (e.g. Aschauer, 1989, Duffy-Deno and Eberts, 1989), as well as the more generalised Translog[4] form appearing in later studies (e.g. Conrad and Seitz, 1994).

ECMT (2001) reported that the data used in these studies could be broadly categorised as follows:

- time-series data – data that are collected from one country or region over a certain time period
- cross-section data – data that are gathered from a number of countries and regions at one point in time
- "pooled" data - a combination of observations for several time periods and several cross-sectional areas.

[2] A Cobb-Douglas function is one functional form of PF where the elasticity of substitution between the input factors for a constant level of output is equal to unity i.e. a 10% change in the input price ratio will lead to a 10% change in the input amount ratio in the opposite direction (Heathfield and Wibe, 1987).

[3] As explained by Heathfield and Wibe (1987), a CES function is one which exhibits constant elasticity of substitution between capital and labour.

[4] As explained in Heathfield and Wibe (1987), Translog stands for Transcendental Logarithmic Functions; in this functional form, the returns to scale are allowed to change with output and or input proportions.

In terms of data types that were used in previous studies, earlier work (e.g. Eberts, 1986, Aschauer, 1989) were largely based on public capital stock (which included transport investments) while recent studies (e.g. Graham, 2005, 2006b) made use of an effective urban density component. While the productivity impact estimated using public capital stock may not be totally attributable to agglomeration effects associated with transport projects, the findings of these studies may offer some inferences on their significance. On the other hand, the findings of recent studies that made use of an effective employment density component are of direct relevance to the research focus of this research. Section 2.6 reviews the past studies that made use of both data types.
While the PF approach is widely applied in earlier studies, recent work by ECMT (2001) and Eijgenraam at al. (2000b) have suggested that this approach may not be suitable for the evaluation of a specific project's indirect welfare effects because of the following two reasons.

- The outcome of such econometric analysis is often not clear on the impact of the investments on the cause or effect of economic growth, or combination of the two.
- The outcomes of the assessment also vary widely and no distinction is made between the direct and indirect effects.

In addition, it is also potentially time consuming and expensive to identify and collect data for all the independent variables that must be included in the regression model (TRB, 1998). TRB (1998) also highlighted that because some of the independent variables are likely to be correlated, there may be effects related to multicollinearity.

2.5.1.4 Computable General Equilibrium (CGE) Modelling

Eijgenraam et al. (2000b, page 113) highlighted that transport investments "affect not only the directly involved parties, but also other actors in the economy". Hence, they highlight that a national-economic analysis of the project is necessary to properly capture a more complete picture of the overall benefits and dis-benefits (Eijgenraam et al., 2000b). Various studies (e.g. TRB, 1998, Eijgenraam et al., 2000b and Dixon et al., 2002a) suggest that a CGE model, which is a detailed representation of a region's economy as a system of markets and their interrelationships, is able to demonstrate how a transport project might impact on the various sectors.

CGE models (also known as Applied General Equilibrium models) originated from Input-Output models[5] in the 1930s and incorporated the economy-wide mathematical programming models which were developed in the 1950s and 60s (Dixon and Parmenter, 1994). The first CGE model was developed by Leif Johansen for the Norwegian economy in 1960, following which there was a surprisingly long inactive period in the development of CGE modelling until the 1970s (Dixon and Rimmer, 2010). Since then, there has been increasing interest in CGE modelling as it offers a powerful platform to provide useful simulations and plausible predictions of the effects of shocks[6] to the world economy which were away from the established trends (Dixon and Parmenter, 1994). CGE modelling is today an established field of applied economics which is used widely in policy making and in business (Dixon and Parmenter, 1994).

In recent years, there has been considerable use of CGE modelling to evaluate transport investments although most of these are on transport construction projects (Gwee and Madden, 2010). The rising popularity of CGE modelling in the evaluation of transport proposals is due to its capability to demonstrate all economic welfare effects of the transport project, including those that occur outside the transport sector (Eijgenraam et al., 2000b) - Section 2.6.5 will further elaborate on the development of CGE modelling of the transport dimension over the years and present the recent studies that estimated the wider economic benefits of transport projects using CGE models.

TRB (1998) and Gibbons and Overman (2009) also noted that such economy-wide models can also differentiate between short-term impacts of constructing a transit investment and the long-term, permanent impacts, which is important because many of the economic benefits associated with a transit system lag many years after implementation.

However, while CGE models have the above-mentioned advantages, they tend to be costly and require substantial expertise on the part of the analyst to identify the appropriate inputs and interpret the results (Eligenraam et al., 2000b).

---

[5] An input-output model is one which uses a matrix representation to specify the linkages between components of the economy of a nation or region so as to predict how the various economic actors would respond to changes in activity variables and prices (Dixon et al., 1992).

[6] In CGE terminology, the process of inputting any impact into the economic model so as to simulate its impact to the economy is known as a “shock” (Dixon et al., 2002a).

Australia has a long history of developing and using CGE models in economic policy reform (Powell and Snape, 1993). Fundamental to the popularity of CGE modelling in Australia was the Australian government's decision in 1975 to establish the IMPACT project research team which today forms the Centre Of Policy Studies (CoPS) at Monash University (Dixon et al., 2002a).

The best known of the CGE models developed by CoPS is the ORANI model, which was Australia's first major CGE model developed in the mid-1970 (Powell and Snape, 1993). Since then, several multi-regional CGE models have been constructed based on the ORANI principles over the last three decades. These include the Monash Multi-Regional Forecasting model (MMRF) which is today used extensively for policy analysis in Australia (Dixon et al., 2002a) and the ORANI-G which is used as a teaching model as well as the template for the economic models for many countries including China, Japan, Denmark and Ireland (Horridge et al., 1998). While the ORANI-style model is presently used extensively for the analysis of public policies and infrastructures in Australia (Dixon et al., 2002a), to the best knowledge of the author, there is no published work to date that uses the ORANI model to estimate the agglomeration benefits associated with urban passenger rail.

The other CGE model that is also used for economic analysis in Australia is the IMP[7] model developed by the National Institute of Applied Economic and Social Research (NIEIR) (Brain, 1977, 1986). This model was used to evaluate the flow-on economic benefits of a possible freeway along the Scoresby corridor in metropolitan Melbourne, Australia (Sinclair Knight Merz, 1998).

2.5.1.5 Assessment

Table 2.1 presents a synthesis of the four existing measurement approaches identified in literature, highlighting their relative strengths and weaknesses. It appears from Table 2.1 that there is no ideal method to estimate agglomeration effects associated with a rail project. A research framework that integrates these approaches may therefore enable this study to fully explore the agglomeration effects in urban rail. In particular, the use of a CGE model could help to better understand how agglomeration economies in urban rail may percolate through the various sectors and regions.

[7] As explained in Brain (1977, 1986), IMP model is the abbreviation of the Institute of Applied Economic and Social Research Multi-Purpose Model of the Australian Economy.

Table 2.1: Strengths and weaknesses of the four methods to estimate wider economic benefits

Approach	Comparative Analysis	Surveys and Interviews	Econometric Analysis	CGE Modelling
Strengths	▪ Offer valuable experience from similar projects elsewhere, ▪ Relatively low cost and easy to administer, ▪ Powerful marketing tool which can reach a wide range of audiences; and ▪ Easy for decision maker to understand.	▪ May offer a useful approach to gather information about productivity impacts of transport improvements to businesses, ▪ Easy and relatively inexpensive to use; and ▪ Serves dual purpose of educating the public about the proposed investment.	▪ Widely applied which suggest that it is relatively easy to use; and ▪ Allows a direct specification of an agglomeration variable.	▪ Good for comparing alternative proposals at the regional or State level as well as evaluate large, individual projects, ▪ Able to demonstrate all welfare effects of a transport project, including those that occur outside the transport sector; and ▪ Can also differentiate between short-term impacts of constructing a transit investment and the long-term, permanent impacts - which is important because many of the economic benefits associated with a transit system lag many years after implementation.
Weaknesses	▪ Such case comparisons could often mislead decision-makers and the public into thinking that experience elsewhere could be replicated in their communities.	▪ Practical limitations and require careful design, ▪ It is not easy to distinguish between direct and indirect effects in surveys and interviews, ▪ The information provided by the respondents is based on their opinions, perceptions and stakes in the project. They may therefore bias their response or their input may not always coincide with their actual behaviour; and ▪ The sample is often structurally distorted as the survey / interview is often conducted among potential users, or more generally, among those directly involved.	▪ May not be suitable for the evaluation of a specific project's indirect welfare effects because of the following reasons: ○ The outcome of such econometric analysis is often not clear on the impact of the investments on the cause or effect of economic growth, or combination of the two; and ○ The outcomes of the assessment also vary widely and no distinction is made between the direct and indirect effects. ▪ Potentially time consuming and expensive to collect data for the variables in the regression model, and ▪ May also have effects pertaining to multicollinearity.	▪ Costly to develop and maintain; and ▪ Requires substantial expertise on the part of the analyst to identify the appropriate inputs and interpret the results.

Source: Developed from Gibbons and Overman (2009), Vickerman (2008a), ECMT (2001), Eijgenraam et al. (2000a, 2000b) and TRB (1998).

2.5.2 Comparative Assessment of International CBA Practices on Urban Rail

As part of the literature review for this research, the CBA approaches on urban rail project evaluation of 12 countries (comprising Australia, the US, the UK, Canada, New Zealand, Germany, Holland, France, Japan, Hong Kong, the Republic of Korea and Singapore) were compared. This work of Gwee et al. (2008) aims to inform the research on the status of agglomeration benefits in international CBA approaches for urban rail projects and the evaluation methods adopted by various countries to measure such effects.

The 12 countries included in this comparative assessment were selected based on the following 3 considerations.

i. The 12 countries have cities that feature highly in the Mercer Quality of Living Survey (Mercer Consulting Group, 2009), The Economist's World's Most Liveable Cities (The Economist Intelligence Unit, 2009) and the Monocle's Most Liveable Cities Index (Monocle, 2009). The rationale is that all these three renowned surveys have considered public transportation as a criterion in their ranking; it is reasonable to assume that with their good public transportation systems, these countries are likely to have also established a comprehensive assessment framework for their public transport investments.

ii. The selected countries also included "affluent" Asian countries such as Singapore, Hong Kong and the Republic of Korea in view of their high quality urban train systems. The rationale here is that, given their quality rail system, they may have also established a more comprehensive economic appraisal framework.

iii. Finally, the availability of published National Guidelines or evidence from past studies was also a criterion in the selection of countries for this assessment. In most cases published National Guidelines were used to inform about CBA approaches. For Japan, France, Germany, Hong Kong, Republic of Korea and Singapore the guidelines are not published or available for our analysis. In these cases, CBA approaches were derived from research papers (such as Morisugi, 2000, Quinet, 2000 and Rothengatter, 2000) or obtained via email correspondence with the relevant authorities.

Table 2.2 summarises the comparative analysis of the CBA approaches among the twelve countries selected. The assessment showed that there remain considerable differences in the CBA approaches for rail projects amongst countries, despite the long history of transport project evaluation.

In the context of agglomeration benefits (shown highlighted in Table 2.2), only Germany, New Zealand, the UK and the Netherlands among the 12 countries have incorporated such wider economic benefits (to at least some extent) in their current economic appraisal framework. The countries that have not included this effect have largely cited the lack of research and understanding in this area - such as the appraisal framework of Australia (Australian Transport Council, 2006, Abelson, 2009) - or concerns of double-counting - such as the American guidelines (Federal Transit Administration, 2007). A critique regarding the issue of double-counting is presented at the end of this section.

Table 2.2: Comparative assessment of international urban rail project evaluation approaches

Parameter	Details		Australia	NZ	USA	Canada	UK	France	Holland	Germany	Japan	Republic of Korea	HK	S'pore
Costs	Capital costs		√	√	√	√	√	√	√	√	√	√	√	√
	Operating and maintenance costs		√	√	√	√	√	√	√	√	√	√	√	√
	Costs to mitigate negative effects of the project		√	√		√	√		√	√		√	√	
	Costs to improve other parts of the transport system		√		√									√
	Residual value of the asset		√			√	√	√	√		√	√	√	
Benefits (monetised)	PT users	Travel time savings	√	√	√	√	√	√	√	√	√	√	√	√
		Fare savings and out-of-pocket savings	√	√	√	√	√	√	√	√	√			
	Auto users	Travel time savings	√	√	√	√	√	√	√	√		√	√	√
		Operating cost savings	√	√	√	√	√	√	√	√		√	√	√
		Vehicle ownership & maintenance cost savings	√		√									
	Truck users	Travel time savings	√	√	√	√						√	√	√
		Operating cost savings	√	√	√	√						√	√	√
	Pedestrains / Cyclists	Travel time savings	√		√									
		Vehicle ownership & maintenance cost savings	√		√									
	Externalities	Air Pollution	√	√	√	?		√	√	√	√	√		
		Green house emission	√	√		?		√	√		√	√		
		Water quality impact	√		√	?			?					
		Noise impact	√	√	√	?	√	√	√	√	√	√		
		Impact to nature and landscape	√			?			?					
	Others	Accident cost savings	√	√	√	√	√	√	√	√	√	√	√	√
		Savings in "avoided costs"	√	√	√					√				
		Option Value			√									
		Agglomeration Benefits		√			√		√	√				
		Enhancement to Property Values							?					
Discount Rate	Method of Derivation	Marginal Rate of Return on Private Investment		√	√	√					X	√	√	
		Social Marginal Rate of Time Preference					√							√
		Government's Borrowing Rate	√						√					
		Weighted Average Approach												
		Shadow Price of Capital' Approach						√						
		Optimal Growth Rate Approach								√				
	Value Adopted		to use discount rate norminated by funding body	8%	7% - 10%	10%	2.5% - 3.50%	8%	4%	3%	4%	6.5%	depend on rail operator	4%
Evaluation Period (yrs)			50	30	20	30	60	30	Tied to project lifespan (max 100 yrs)	40	30-50	20 - 30	30 - 120	60
Decision Criteria		Nett Present Value (NPV)	√		√	√	√	√	√			√	√	
		Benefit-Cost Ratio (BCR)	√	√						√	√	√		√
		Internal Rate of Return (IRR)						√	√			√	√	

Sources : Developed from DfT (2009), NZTA (2008), Lim (2008), Kim (2008), van der Hoorn (2008), Zwartjes (2007), Land Transport New Zealand (2005, 2007), Federal Transit Administration (2007), Department of Transportation (2010), Lam (2007), AusRoads (2006), Australian Transport Council (2006), Department of Infrastructure (2005b), HM Treasury (2003), Young (2002), Eligenram et al. (2000a, 2000b), Lee Jr (2000), Hayashi and Morisugi (2000), Nakamura (2000), Quinet (2000), Rothegatter (2000), Vickerman (2000), Treasury Board of Canada Secretaria (1998), TRB (1996, 1998, 2002), Transport Canada (1994)

Legend: √ - monetised and included; X – no information; ? – unclear whether the parameter is included; blank – not monetised

Based on the work of Rothengatter (2000) and Hayashi and Morisugi (2000), it is understood that Germany considers agglomeration effects as a benefit arising from improved land use. There was, however, no published information available on the details of how these impacts are estimated in Germany.

DfT (2009) and New Zealand Transport Agency (NZTA) (2008) indicated that both the UK and New Zealand estimate the agglomeration benefits associated with transport improvements using agglomeration elasticities. These were based largely on the work of Graham (2005, 2006b). Essentially the approach entails the estimation of the change in employment densities (i.e. the change in the accessibility between firms and employees) of the areas benefiting from the transport improvement under study. The agglomeration benefits are then estimated using the agglomeration elasticities and the GRP contribution per worker of that region. Consultation with DfT (2010)[8] however suggests that, while they do consider agglomeration benefits in their economic appraisal framework, it is not mandatory to include these benefits in the overall Benefit-Cost Ratio of the transport projects.

In the case of the Netherlands, the national guidelines do not detail a methodology to estimate agglomeration benefits, as "there is no approach for the measurement of indirect welfare effects that is satisfactory on all counts" (Eligenraam et al., 2000b, page 114). The Dutch CBA guidelines, however, indicate that they made use of a national CGE model to estimate these wider economic benefits. They also acknowledged the significance of such indirect welfare effects and highlighted that such benefits should "be included in the project appraisal at an early stage and in appropriate depth" (Eligenraam et al., 2000b, page 114).

In summary, the comparative assessment of CBA practices among the 12 countries reveals that agglomeration benefits are not included in the CBA framework of most countries; only a few countries have incorporated these effects in their current CBA framework (Gwee et al., 2008). While there are generally 4 methods identified in literature to estimate these effects (as shown in Section 2.5), countries that do consider agglomeration effects in their CBA framework estimate them using agglomeration elasticities or an economy-wide modelling approach. This suggests that they are the best approaches today. Section 2.6 presents a survey of past studies, highlighting both the findings as well as the method of estimation.

[8] Obtained via personal communication.

2.5.3 Critique on Double-Counting Issue

Federal Transit Administration (2007) and TRB (1998) highlighted that any wider economic benefits generated by transport investments are capitalised into the lease rates and sale prices of properties. They argued that the improved accessibility is due, in large value, to the travel time savings which is already well-captured in the conventional CBA framework; therefore, adding together the travel time benefits and the property value benefits would be counting the same impact twice.

However, DfT (2006) commented that in some circumstances, the benefits of transport improvement exceed the direct time savings to the commuters or the firms they work for. DfT (2006, page 13) highlighted that "in such cases, the willingness-to-pay" approach will not be an accurate estimate – and will usually be an underestimate – of the true benefits to society". This is because time savings are counted at the value that firms or individuals put on them; they will therefore reflect the private value rather than the social value.

Going along DfT's (2006) argument, if a firm decides to relocate nearer a cluster due to lower transport costs, the societal benefits would exceed that enjoyed by the relocating firm. In this instance, the conventional CBA would only capture the direct (travel) cost savings to each firm, but it will not have included the benefits to the other firms in terms of the higher productivity from increased agglomeration. Such agglomeration effects are therefore one of the market imperfections that are currently not captured in conventional CBA.

One of the key contributions of this research is to clearly demonstrate the regions that will benefit and dis-benefit from an urban rail constraint via the use of a CGE model. This investigation is reported in Chapter 8. This finding addresses the double-counting ambiguity raised by critiques of agglomeration benefits.

2.6 A Review of Past Studies

Over the last 20-30 years, many studies have examined the relationship between public capital stock (which includes transport infrastructure provision) and economic growth. However, the outcome of these studies is unclear - as succinctly summarised by the ECMT (2001, page 13), “while theory and empirical evidence suggest that there is a connection between transport investments and economic developments, the direction of the connection is not always clear”.

Most previous studies (e.g. Aschauer, 1989, Graham, 2005) have argued that transport plays an important role in sustaining cities and supporting urban agglomerations; this in turn can generate external benefits to the economy which are not included in the conventional economic appraisals for transport investment. On the other hand, earlier work by several other researchers (e.g. Hall and Hass-Klau, 1985, Haughwout, 1999) were sceptical about these agglomeration effects associated with transport infrastructure.

As highlighted in the preceding section, earlier studies were largely based on public capital stock while recent studies made used of an effective urban density component. While the productivity impact estimated using public capital stock may not be totally attributable to agglomeration effects associated with transport projects, the findings of these studies may provide some insight on their significance. On the other hand, the finding of recent studies that made use of an effective employment density component is of direct relevance to the research focus of this research.

In addition, Eberts and McMillen (1999) also highlighted that most of the past studies had only examined the sole impact of public infrastructure provision on productivity and only a few attempted to examine the combined effects of agglomeration and public infrastructure provision in their analysis of urban productivity. They suggested that the consideration of both effects simultaneously on urban productivity is the correct approach to estimate these types of benefit. Further to that, this literature review has also revealed that a recent development in this area is the use of agglomeration elasticities spearheaded by the work of Graham (2005, 2006, 2007b) as well as CGE modelling to estimate the wider economic impacts of transport infrastructure (Vickerman, 2007b, Brocker, 2004).

To clearly present the findings of past studies, this review is organised in the following sequence.

- **Section 2.6.1 - Studies that found a Positive Link between Public Infrastructure Provision and Productivity** presents the findings of those studies that found a positive impact of public infrastructure provision on productivity using public capital stock data.
- **Section 2.6.2 - Studies that found a Weak Link between Public Infrastructure Provision and Productivity** presents the findings of those studies that found a weak impact of public infrastructure provision on urban productivity using public capital stock data.
- **Section 2.6.3 - Studies that Considered Both the Effects of Agglomeration and Public Infrastructure Provision on Productivity** reviews the few studies that analysed the dual effects of agglomeration and public infrastructure provision on productivity using macro data.
- **Section 2.6.4 - Studies that made use of Spatial Data and Density Measures to estimate Agglomeration Economies** presents the findings of those studies that use spatial data and density measures to estimate agglomeration economies.
- **Section 2.6.5 - Studies that Used CGE Models to Estimate the Wider Economic Impacts of Major Transport Infrastructure** presents the studies that used CGE models for the assessment of the wider economic impacts of major transport infrastructure projects; this section also outlines how the CGE modelling of the transport dimension has progressed over the years.

2.6.1 Studies that found a Positive Link between Public Infrastructure Provision and Productivity

The work of Eberts (1986) suggested that public infrastructure is an important element of agglomeration economies. Using econometric analysis with a Translog production function technique on the public capital stock data for 38 metropolitan areas in the US from 1958 to 1981, Eberts (1986) found that the public capital stock is an important element of agglomeration economies. He estimated that an elasticity of output with respect to public capital stock of 0.03, which suggests that a 1% increase in public capital stock increases productivity by 0.03%.

Aschauer (1989) also suggested a positive connection between transport investment and economic growth when he compared the rate of economic growth with the transport infrastructure investment in different US states from 1949 to 1985. Using econometric analysis with a Cobb-Douglas production function, Aschauer (1989) suggested that the elasticities of productivity to the movement of public capital were in the range of 0.38 to 0.56, depending on the choice of the sample period.

Using 1980 to 1984 data and a CES production function technique, Duffy-Deno and Eberts (1989) argued that public infrastructure is an important element in the regional production process, which has "long-run consequences for enhancing a region's productivity and thus its competitive edge". Duffy-Deno and Eberts (1989) estimated that a 10% increase in public capital will generate a 0.81 – 0.94% increase in personal income per capita.

Eberts (1990a, 1990b) also suggested that public infrastructure stimulates economic activities, "either by augmenting the productivity of private inputs or through its direct contribution to the output". He indicated that public infrastructure may also attract households and firms which will further contribute to an area's growth. His investigation showed that investment in communications and transport infrastructure appeared to have the most significant impact on regional growth. Ebert's (1990b) work suggested that a 1% increase in public infrastructure investment can bring about 0.49% increase in Total Factor Productivity[9].

[9]According to Williamson (2002), TFP is a measure of output growth that is not accounted for by growth in inputs or economies of scale. TFP essentially captures the effects of the more efficient and innovative use of labour and capital as well as technological progress (Socio-economic & Environmental Research Institute, 2008).

By examining the impact of public infrastructure on output, employment growth and private investment at the state and regional level, Munnell (1990a) concluded that those states that have invested more in infrastructure tend to have greater output, more employment growth and more private investment. This suggested that public capital investment does have a positive impact on regional economic performance. She found highways and water and sewer systems most likely to have a statistically important relationship with productivity. Her econometric analysis using the Cobb-Douglas production function technique suggested that a 1% increase in public investment would raise labour productivity by 0.31% to 0.39% (Munnell, 1990b).

Lynde and Richmond (1992, 1993) repeated the analysis carried out by Aschauer (1989) using largely the same data set but a different form of production function. While their econometric analysis supported the findings of Aschauer (1989) that public capital is an important part of productivity, their estimation that a 1% increase in public capital will increase productivity by about 0.2% is approximately half of the value estimated by Aschauer (1989).

Conrad and Seitz (1994) used macro data from West Germany for their econometric analysis. Their work suggested that a 1% increase in public infrastructure investment would lower production cost by about 0.36% in the manufacturing sector. This is in the same order of magnitude as the elasticities found by Aschauer (1989). Conrad and Seitz (1994) also indicated that a 1% increase in public capital would lower production cost by about 0.07% and 0.74% for the trade and transport as well as the construction sectors respectively.

Using a similar technique as Conrad and Seitz (1994) but a slightly different data set, Seitz and Licht (1995) estimated that the average elasticity of private production cost for the manufacturing industry with respect to public capital is about -0.216. Their result suggested that regional governments can increase the attractiveness of their regions by investing in public infrastructure.

Johannson et al. (1996) (cited in ECMT (2001)) compiled productivity elasticity results using time series data of capital investment from different countries. As shown in Table 2.3, their work estimated an output elasticity range of 0.34 - 0.70 for Australia.

Table 2.3: Output elasticities derived from aggregated production functions (based on time series data)

Country	Output elasticity
United States	0.29-0.64
Netherlands	0.48
Japan	0.15-0.39
Germany	0.53-0.68
Canada	0.63-0.77
Belgium	0.54-0.57
Australia	0.34-0.70
France, UK, Finland, Norway, Sweden	Wide range between highest and lowest value

Source: Johansson *et al.* (1996), *Infrastruktur, produktivitet och tillväxt - En kunskapsöversikt*, KTH, Stockholm.

Source: ECMT (2001)

The econometric work of Prud'homme and Lee (1999) suggested that the level of transport infrastructure provision in a city influences the speed that people and goods are moved in the city. According to them, this has a positive relationship with the efficiency and productivity of a city. Using data from 22 French cities, Prud'homme and Lee (1999) estimated that an increase in transport investment which would result in a 10% increase in the speed of people and goods movement in the city would in turn bring about a 2.7% increase in productivity.

Cervero (2001) carried out econometric analyses at a macro level (using data from 47 US metropolitan areas) as well as at a micro level (using data from San Francisco Bay Area which was divided into 34 super districts). His macro analysis showed that metropolitan areas with the worst freeway congestion were also the best economic performers. Cervero (2001) explained that high employment density which correlates positively with high economic performance, brings with it high levels of traffic congestion.

Cervero's (2001) micro analysis suggested that a 10% increase in commute speed will bring about a 1% increase in workers' output, all else being equal. He highlighted that the findings of the micro and macro analysis are not contradictory because, while across regions, slow commute speed is a by-product of economically vibrant areas, within metropolitan areas, sub-areas with better performing highways enjoy better economic advantages.

The findings of Gibbons and Machin (2003) also suggested that there may be wider economic benefits from transport improvements than those captured by savings in commuting time cost. Using econometric analysis and a hedonic pricing method[10], they estimated that a 1km reduction in distance to rail access is valued at around 1.5% of the local property prices. Gibbons and Machin (2003) suggested that for a home-buying commuter, the benefits of better accessibility to transit systems as reflected in the higher property prices are two-fold. Firstly, there is a direct saving on travel time and, secondly, rail access changes the distribution of job types and wages that are available by reducing commuting costs to more diverse and potentially better-paid jobs in the city.

2.6.1.1 Assessment

Table 2.4 presents a synthesis of the above studies. Most of the studies made use of public capital stock data, with the exception of Prud'homme and Lee (1999), Cervero (2001) as well as Gibbons and Machin (2003), which were based on transport capital alone. Generally, these studies suggest that a 1% increase in public capital investment is associated with a 0.03% - 0.56% increase in economic productivity. While the productivity impact estimated using public capital stock may not be totally attributable to agglomeration effects associated with transport projects, the positive findings suggest that agglomeration effects associated with transport improvements might be substantial. This proposition is supported by the findings of those studies which made use of transport capital. In addition, the wide spread of results reflects the difficulties in this research field and suggests that there is room to improve the methodology for estimating wider economic benefits of this kind.

It is observed that studies which used "pooled" data sets (e.g. Duffy-Deno and Eberts, 1989) generally yield a lower output elasticity compared to those which analysed time series data (e.g. Johansson et al. (1996) cited in ECMT (2001)) - as shown in Table 2.4, Duffy-Deno and Eberts (1989) found an output elasticity of 0.081% – 0.094%; on the other hand, Johansson et al. (1996) estimated elasticities of above 0.50 for several countries.

[10] According to Garrod and Willis (1999), the hedonic pricing method models an individual's willingness-to-pay to consume a particular good as a function of the levels of the good's characteristics. They highlighted that the most common application of this method is in relation to the public's willingness-to-pay for housing where each property may be assumed to constitute a distinct combination of attributes that determine the price that a potential buyer or tenant is willing to pay.

Table 2.4: Synthesis of studies that found a positive link between public infrastructure provision and productivity

s/no.	Study	Study Approach	Data Used	Findings
1	Eberts (1996)	Econometric analysis using a Translog production function.	Public capital stock (including roadways, highways, bridges and tunnels) for 38 SMSAs (defined in the US Department of State (2008) as Standard Metropolitan Statistical Area[11]) in the US from 1958 to 1981.	In this study, Eberts (1986) estimated a public capital output elasticity of productivity of 0.03 for the manufacturing sector.
2	Aschauer (1989)	Econometric analysis using a Cobb-Douglas production function.	The US 1949 – 1985 period data on real aggregate output of goods and services of the private sector, private capital stock, productivity and public capital stock.	Aschauer (1989) suggested that the elasticities of productivity to the movement of public capital is in the range of 0.38 to 0.56, depending on the choice of the sample period.
3	Duffy-Deno and Eberts (1989)	Econometric analysis using a CES production function.	The 1980 – 1984 data (on wage level, price level of labour, private capital stock, energy cost and public capital stock) from 28 US SMSAs.	Duffy-Deno and Eberts (1989) estimated that a 10% increase in public capital will generate a 0.81 – 0.94% increase in personal income per capita.
4	Eberts (1990)	Econometric analysis using a CES production function.	The1965 – 1977 data on Total Factor Productivity (TFP) and the public capital stock for 36 US metropolitan areas.	Eberts (1990b) suggested that a 1% increase in public capital is associated with a 0.49% increase in TFP.
5	Munnell (1990a, 1990b)	Econometric analysis using a Cobb-Douglas production function.	The 1909 – 1989 output per hour data as well as the level of private and public capital stock between 1948 and 1989 in the US.	Munnell (1990a, 1990b) suggested that a 1% increase in public capital could raise productivity by 0.31 to 0.39%.
6	Lynde and Richmond (1992, 1993)	Econometric analysis using a Translog production function.	The 1958 – 1989 data on real aggregate output of goods and services of the private sector, private capital stock, productivity and public capital stock in the US.	The analysis of Lynde and Richmond (1993) estimated an average elasticity of output with respect to public capital is about 0.20 which is approximately half of the value estimated by Aschauer (1989).
7	Conrad and Seitz (1994)	Econometric analysis using a Translog cost function[12].	The annual data on gross output, labour (as in total hours worked and total compensation), price of intermediate goods, net private capital stock as well as public capital stock between 1961 – 1988 for three sectors of West German economy - manufacturing, construction and trade and transport.	Conrad and Seitz (1994) estimated that a 1% increase in public capital could lower production cost by 0.36% in the manufacturing sector, 0.07% in the trade and transport sector, 0.74% in the construction sector.

[11] According to the US Department of State (2008), a SMSA is a statistical unit of one or more counties that focus on one or more central cities larger than a specified size, or with a total population larger than a specified size. It is a reflection of urbanisation.

[12] According to Heathfield and Wibe (1987), a Translog cost function is set up in the same way as a Translog cost production function but in terms of costs and prices rather than in terms of quantities.

Table 2.4: Synthesis of studies that found a positive link between public infrastructure provision and productivity (cont')

s/no	Study	Study Approach	Data Used	Findings
8	Seitz and Licht (1995)	Econometric analysis using a Translog cost function.	The data on output, private capital, labour and public infrastructure (which included utilities, communication, transport and land development) between 1971 – 1988 data for the manufacturing industry in 11 states of West Germany.	Seitz and Licht (1995) estimated the elasticity of private production cost with respect to public capital to be about -0.216.
9	Johansson et al. (1996) (cited in ECMT (2001)	Compilation of results from different countries based on time-series data sets	Time-series data sets on capital investment.	Johansson et al. (1996) estimated a range of output elasticities; several countries have output elasticities of above 0.50. Specifically for Australia, their study found a range of 0.34- 0.70.
10	Prud'homme and Lee (1999)	Two stage econometric analysis to correlate (a) output per worker and labour market size and (b) labour market size as a function of city size, speed and sprawl.	Population (as an indication of city size), speed of travel (as an indication of efficiency of the transport network) and journey time (as an indication of city sprawl) of 22 French cities.	Prud'homme and Lee (1999) estimated the elasticity of the labour market size with respect to speed is about 1.5. They also estimated the elasticity of productivity to effective labour market size to be about 0.18. These findings essentially suggest that a 10% increase in speed of people and goods movement in the city would increase productivity by 2.7%.
11	Cervero (2001)	Econometric analysis using production function and regression technique was carried at both the macro and micro level.	Data on the productivity per worker, population size and geographic scale of an area, relative proximity of firms to labour markets, density and degree of primacy in an area and the relative speed and performances of services in an area.	At the macro analysis, Cervero (2001) found that metropolitan areas with the worst freeway congestion were also the best economic performers. His micro analysis suggested that a 10% increase in commute speed will bring about a 1% increase in workers' output, all else being equal.
12	Gibbons and Machin (2003)	Econometric analysis using hedonic pricing models (see footnote explanation on pg 24 by Garrod and Willis (1999).	The 1997 to 2001 property prices within 30km of rail access in London and the wider metropolitan area of South East England.	Gibbons and Machin (2003) estimated that a 1km reduction in distance to rail access is valued at around 1.5% of the local property prices.

2.6.2 Studies that found a Weak Link between Public Infrastructure Provision and Productivity

While the studies reviewed in Section 2.6.1 suggested that public capital / transport infrastructure provision has a positive effect on economic productivity, the following studies were sceptical about the agglomeration effects of transport investment.

Hall and Hass-Klau (1985) carried out a comparative analysis of thirteen cities in Britain and Germany. Their work examined various parameters such as passenger volume, the financial performance of the urban passenger transport undertakings as well as population and employment growth pattern, retail turn-over and property values of these cities between World War Two and the 1980s. They concluded from their comparative analysis that the processes of urban growth and decline have "deep and subtle causes" in which transit investment does not play a large role in (Hall and Hass-Klau, 1985, page 169).

A dissenting view was also shared by Hulten and Schwab (1991) who doubted the importance of public infrastructure as a key determinant of regional productivity growth. Their comparative analysis showed that productivity actually grew faster in the older, declining regions of the US which suggested that "there is no systematic relationship between the regional growth rate of public capital and the regional growth rate of productivity". Using data from 9 US regions over 16 years, their econometric analysis using production function techniques indicated that the link between the regional growth rate of public capital and the regional growth rate of productivity is weak.

Using annual observations on 48 contiguous states in the US from 1969 to 1983, with a Cobb-Douglas production function, Garcia-Mila and McGuires' (1992) econometric analysis found that investment in education potentially has a stronger impact on gross state product than highway capital. Based on the resultant coefficients of their regression, Garcia-Mila and McGuires (1992) concluded that highway capital does not appear to have a relatively large effect on the gross state product.

Holtz-Eakin (1993) carried out a comparative analysis of the economic performance and the growth rate of the public capital stock across all 51 states in the US using data from 1961 to 1988. He concluded that "a broad-based spending program for additional infrastructure in the US is unlikely to augment economy-wide productivity growth".

Applying econometric analysis on essentially the same set of data, Holtz-Eakin (1994) also suggested that previous regression analysis that estimated that transport infrastructure has large, positive effects on productivity appears to be a result of an "inappropriately restrictive econometric framework". His analysis found that the best estimate of the elasticity of productivity with respect to public capital "is roughly zero".

By analysing the public infrastructure investment and employment density pattern for 48 states in the US between 1974 and 1992, Haughwout (1999) suggested that the provision of new infrastructure can induce the decentralisation of employment as it tends to redistribute economic growth from dense to less dense metropolitan areas. This, he highlighted will diminished the agglomeration benefits offered by cities.

2.6.2.1 Assessment

Table 2.5 presents a synthesis of the above studies. Interestingly, while these studies were sceptical about the agglomeration effects associated with transport improvements, none of them suggested that transport investments would impact economic productivity negatively. In addition, it is also observed generally that the number of studies that found a weak link between public infrastructure provision and productivity is significantly less than those that found a positive relationship (see Table 2.4). This may suggest that agglomeration effects associated with transport projects are valid.

Table 2.5: Synthesis of studies that found a weak link between public infrastructure provision and productivity

s/no	Study	Study Approach	Data Used	Findings
1	Hall and Hass-Klau (1985)	Comparative analysis of 13 cities (seven in Germany and six in Britain) with respective to their growth and the development of their passenger rail network since World War Two.	The data analysed included direct effects such as the passenger levels, financial performance of the urban passenger transport undertakings and indirect effects on urban activity patterns such as population and employment growth, retail turn-over and property values.	From their 14 months of work, Hall and Hass-Klau (1985) concluded that "transit investment has not had much effect on the city". They therefore suggested that the processes of urban growth and decline have "deep and subtle causes" in which transit investment does not play a large role in.
2	Hulten and Schwab (1991)	Econometric analysis using a CES production function.	The 1951 – 1986 US regional data on gross regional output, labour input (employment and wage level), intermediate goods (including materials and energy), capital input and public capital stock.	Hulten and Schwab (1991) suggested that the link between the regional growth rate of public capital and the regional growth rate of productivity is weak.
3	Garcia-Mila and McGuire (1992)	Econometric analysis using a Cobb-Douglas production function.	14 annual observations for GDP and labour for 48 states in the US from 1969 to 1983 as well as the annual highway capital (new and maintenance) by state and local government and the total state and local expenditures for K-12 and post-education.	The outcome of their analysis suggested that investment in education potentially has a stronger impact to gross state product than highway capital. Their regression estimated coefficient values of 0.356, 0.165 and 0.045 for labour, education and highway investment respectively. From their findings, they concluded that highway capital does not appear to have a relatively large effect on the gross state product.
4	Holtz-Eakin (1993)	Comparative analysis of the economic performance and the growth rate of the public capital stock across all 51 states in US.	The data used was the 1961 – 1988 economic performance and the growth rate of the public capital stock across all 51 states in US.	Holtz-Eakin (1993) concluded that there is no evidence to suggest that public capital "is the key to faster productivity growth in the US".
5	Holtz-Eakin (1994)	Econometric analysis using a Cobb-Douglas production function.	The data on the output, labour, private capital and state and local government capital for 48 US states between 1969 and 1986 – essentially the same set of data used by Holtz-Eakin (1993).	Holtz-Eakin (1994) suggested that the elasticity of productivity with respect to public capital is about zero which implied that "there is no role for public-sector capital in affecting private sector capital".
6	Haughwout (1999)	Comparative analysis using statistical models.	The 1974 – 1992 data on growth in county human capital, public infrastructure, employment density and industrial mix for the contiguous 48 states in the US.	Haughwout (1999) suggested that state infrastructure investments tend to redistribute growth from areas of dense employment to other parts of the state. This redistribution may diminish agglomeration benefits offered by cities which could potentially reduce state growth.

2.6.3 Studies that considered both the Effects of Agglomeration and Public Infrastructure Provision on Productivity

Studies by Mera (1973), Moomaw (1983), Calem and Carlino (1991) and Seitz (1995) are the few exceptions to the general tendency not to consider both the effects of agglomeration and public infrastructure provision simultaneously in an analysis of urban productivity (Eberts and McMillen, 1999).

Mera (1973) utilised econometric analysis via a production function technique for his study. He used three sets of input data including labour, private capital and public capital stock of 46 prefectures in Japan for the period of 1954 to 1963 in his analysis. The level of employment was included in the production function to provide a measure of agglomeration economies while the public capital stock used in his assessment includes highways and railways. By including measures of employment and public capital stock in the production function, Mera (1973) was able to separate contributions of agglomeration economies and public capital stock to productivity advantages of larger cities. His econometric analysis suggested that both employment level (i.e. agglomeration economies) and public capital stock have positive and statistically significant effects on productivity for broad industries in Japan. Mera (1973) estimated an elasticity range of 0.075 – 0.364 between productivity of private capital and public capital investment in transportation and communications.

Moomaw's (1983) econometric analysis included a measure of transportation investment along with a population variable that measured net agglomeration effects. Using 1957 – 1972 data on the US manufacturing activities, he found that public infrastructure, even when included in an equation with population, has a positive effect on the productivity of some US industries within metropolitan areas. He estimated that a 1% increase in highway investment will bring about 0.02% increase in productivity.

Calem and Carlino (1991) also suggested that infrastructure provision and energy endowment are likely to have a positive effect on urban productivity. Their analysis using a CES production function technique indicated that the magnitude of such effects in the largest cities was twice that in smaller cities. They estimated an elasticity of 0.029 for productivity with respect to infrastructure provision and energy endowment for cities with population over 2 million while the values for cities smaller than 2 million ranges between 0.014 - 0.018.

Seitz (1995) explicitly modelled and estimated the effect of both public infrastructure investment and agglomeration economies on the productivity of private manufacturing firms within 85 cities in West Germany. He estimated the public infrastructure investment using the perpetual inventory method[13] while agglomeration effect was measured by the total employment in each city.

Seitz (1995) estimated that that on average, a 1% increment in the provision of public infrastructure could potentially raise productivity through the reduction in private production cost by 0.127%. He suggested that there are significant cost reducing effects associated with the supply of local public infrastructure provision and hence investment in public infrastructure will induce private investment. He also found that a 1% increase in the job density ratio (defined as jobs per 1,000 inhabitants) is associated with a 2% increase in the supply of public infrastructure investment.

[13] As explained in Eberts (1986), under the perpetual inventory method, the capital is measured based on the sum of the value of past capital purchased adjusted for depreciation and discard.

2.6.3.1 Assessment

Table 2.6 presents a synthesis of the above studies. Overall, these studies that considered the combined effects of agglomeration and public infrastructure provision on urban productivity also found a positive relationship between public infrastructure provision and productivity. However, the output elasticities estimated by these studies are generally lower than those that only considered the sole impact of public infrastructure provision on productivity (reviewed in Section 2.6.1). As shown earlier in Table 2.4, those studies that only examined the sole impact of public infrastructure provision on productivity using "pooled" data sets found an output elasticity range of 0.03 – 0.56. In this instance, these studies that considered both effects of agglomeration and public infrastructure provision on urban productivity estimated a corresponding elasticity range of 0.02 – 0.36. This is about 30% - 40% lower than the values estimated by the earlier group of studies. This may suggest that the productive advantage that may be attributed to transport improvement is about 60% - 70% of the overall productivity impact that arise from the improved spatial concentration of economic activity. In addition, the wide disparity in the elasticity estimated suggests that there is a need to improve the methodology for estimating wider economic benefits of this kind.

Table 2.6: Synthesis of studies that considered both the effects of agglomeration and public infrastructure provision on productivity

s/no	Study	Study Approach	Data Used	Findings
1	Mera (1973)	Econometric analysis using a Cobb-Douglas production function.	The data on the basic economic information (including value add, labour force, estimates of private and public capital stock) of 46 prefectures in Japan from 1954 to 1963. The public capital stock included in his assessment includes highways and railways.	Mera (1973) suggested an elasticity range of 0.075 – 0.364 between the productivity of private capital and public investment in transportation and communications.
2	Moomaw (1983)	Econometric analysis using a Cobb-Douglas production function.	Moomaw (1983) used the same set of data as that used by Carlino (1978) i.e. the 1957 – 1972 US data on manufacturing activities which came from the US Census of Manufacturers.	Moomaw (1983) derived a positive coefficient for the highway quality factor which suggested that "highway expenditure enhances productivity". He estimated an average elasticity value of 0.02 for highway among all the industry classes.
3	Calem and Carlino (1991)	Econometric analysis using a CES production function.	The 1957 – 1980 data on wage rate, output, labour and population for 80 US metropolitan areas.	Calem and Carlino (1991) suggested that infrastructure and resource endowment are likely to affect urban productivity and that the effects in the largest cities was twice that in the smaller size groups. They estimated an elasticity value of 0.029 for cities with population larger than 2 million and an elasticity range of 0.014-0.018 for cities smaller than 2 million.
4	Seitz (1995)	Econometric analysis using a Translog cost function.	1980 – 1989 employment and wage rate of the manufacturing industry in 85 West Germany cities and the 1969 – 1989 public infrastructure investment for these cities.	Seitz (1995) estimated that the average elasticity of private production cost with respect to urban infrastructure provision is 0.127 – that is on average, a 1% increase in the provision of public infrastructure will potentially reduce private production cost by 0.127%. He also estimated that a 1% increase in the job density ratio (defined as jobs per 1,000 inhabitants) is associated with a 2% increase in the supply of public infrastructure investment.

2.6.4 Studies that made use of Spatial Data and Density Measures to estimate Agglomeration Economies

Graham (2005, 2006a, 2006b, 2007a, 2007b) carried out extensive research on agglomeration economies associated with transport improvement using data from the UK. He suggested that the transport system can influence the proximity between firms and the labour market to a certain extent and can "change urban or industrial densities by rendering a larger scale of activity more accessible" (Graham, 2006a, page 3). Going along this line of reasoning, Graham (2005, 2006a, 2006b, 2007b) argued that the level of clustering experienced in different parts of the UK can be measured by calculating the effective density of economic activity. He therefore modelled agglomeration economies by estimating the effective employment density (ED_{io}), which is an agglomeration metric that measures the accessibility of workers to firms using Equation 2.2 that contains an implicit transport dimension:

$$ED_{io} = \frac{E_i}{[\sqrt{A_i / \pi}]^{\alpha_o}} + \sum_{j}^{i \neq j} ([E_j].d_{ij}^{-\alpha_o}) \qquad \text{(Equation 2.2)}$$

where

- ED_{io} is the total effective density of employment that is accessible to any firm in industry *o* located in area *i*
- E_i is the total employment in area *i*
- A_i is the area of area *i*
- E_j is the total employment in ward *j*
- d_{ij} is the distance between *i* and *j*
- the value of α_o determines the effect of distance on the strength of density externalities for each industry *o*.

Graham (2005, 2006a, 2006b, 2007a, 2007b) then used this variable in a Translog Production Function model to estimate a series of elasticities of productivity with respect to agglomeration for different industries for the entire UK by applying weighting to various elasticities based on their employment shares in the various regions. His Translog model made used of the turnover of the firms in the study region as the dependent variable with labour, capital and ED_{io} as independent variables (Graham, 2005, 2006a, 2006b, 2007b). The agglomeration elasticities derived by Graham (2005, 2006a, 2006b, 2007b) are essentially the modelled output coefficient of the last independent variable. The agglomeration elasticity is therefore the elasticity of productivity with respect to the effective employment density or change in proximity between workers to firms (DfT, 2009, page 4).

Graham's work, which forms the basis of agglomeration elasticities values adopted by DfT (2009) and NZTA (2008), derived an average agglomeration elasticity of 0.052 for the productivity of the manufacturing industries as a whole with respect to effective employment density; his work derived much higher elasticities for service industries such as Finance and Insurance (0.251), Business and management consultancy (0.298) and even Hotels and restaurants (0.224) are much higher than the average elasticity of 0.052 estimated for manufacturing industries. This suggests that for an area such as the CBD which has a knowledge-based economy with a high concentration of Financial and Business industries, the productivity impact due to an increase in urban size / concentration is envisaged to be significantly higher as compared to a region which is made up largely of manufacturing industries. Using the agglomeration elasticities derived by Graham (2006b), a weighted agglomeration elasticity of 0.216 was estimated for Melbourne CBD. This weighted elasticity essentially means that doubling the employment densities of Melbourne CBD could potentially raise its productivity by an additional 21.6%.

Using a method similar to Graham (2006a), Longworth (2008) explored various measures of agglomeration for metropolitan Sydney. Amongst the different measures of proximity examined, he found the best correlation between effective employment density and the average income per week – although there is still about 40% of the variation unexplained. This suggests that wages or employee compensation earned at the job may offer an alternative measure of proximity. This proposition was supported by the work of Gibbons and Overman (2009) which highlighted that the wages and employment of areas affected by transport improvements may provide a way to measure the effect of transportation on productivity.

Going along Graham's (2005, 2006b) argument that transport improvements can improve the proximity between firms and the labour market, which in turn increases effective employment densities and hence productivity, past studies that examined the elasticities between productivity gains and urban size / employment concentration (i.e. the number of workers per unit area)[14] are of relevance to this research. This research terms such elasticity as productivity elasticity[15].

Aberg (1973) used 1965 – 1968 data on Swedish cities and estimated an elasticity of productivity to city population of 0.02. Using 1958 – 1963 output, capital and labour data for the two-digit manufacturing industries in the US, Shefer (1973) found that both localisation and urbanisation economies do exist in the manufacturing sectors located in metropolitan areas. While he found the localisation economies to vary widely across the industries, he derived an elasticity of 0.20 for urbanisation economies with respect to urban scale[16].

Kawashima (1975) estimated a population elasticity of 0.20 based on a Cobb-Douglas specification production function with 1958 – 1967 data from US three-digit manufacturing industries. His work also concluded that optimal urban size to be about 5.95 million.

Sveikauskas (1975) found that doubling of city size is associated with a 6% increase in labour productivity. He highlighted that these productivity gains are likely to be "a central influence on the existence and prevalence of large cities". Following Sveikauskas (1975), Segal (1976) estimated that regions with a population of at least 2 million had a returns to scale factor that is 8% higher than the other regions.

Fogarty and Garofalo (1978) (cited in Eberts and McMillen, 1999) derived a productivity elasticity of 0.10 based on a CES specification production function and data from the US manufacturing industries. This is noted to be higher compared to the productivity elasticity derived by the earlier studies.

---

[14] This research has consciously defined employment concentration as the number of workers per unit area. This is to differentiate against employment density (which is an agglomeration metric that measures the accessibility of workers to firms) used by Graham (2005, 2006a, 2006b).

[15] It is to be highlighted that productivity elasticity is not the same as agglomeration elasticity.

[16] Shefer (1973) defined urban scale as employment population.

Using the same data set as Segal (1976), Moomaw (1981) estimated a productivity elasticity of 0.027. Moomaw (1981) argued that Segal (1976) had over-estimated the efficiency advantage of large cities, as Segal (1976) had underestimated the capital stocks of the older cities which were overrepresented in the analysis sample. Nonetheless, Moomaw (1981) concluded that, even with the downward revision from Segal's (1976) results, large cities still have substantial productivity advantage. Based on his findings, he suggests that "any effort to revitalise large cities should be focused on non-manufacturing sectors".

Nakamura (1985) applied a Translog specification production function on a 1979 dataset which included private capital and employment for two-digit manufacturing industries in Japan. He concluded that the effects of localisation economies are more significant than urbanisation economies. His work found a productivity elasticity range of 0.0336 – 0.0445.

Also using private capital and employment for two-digit manufacturing industries in Japan (for 1980), Tabuchi's (1986) CES specification production function estimated that labour productivity increases by 4.3% with every doubling of population concentration. This is noted to be close to that estimated by Nakamura (1985).

Henderson (1986) found positive localistion economies. Using data from both the US and Brazil, he estimated a mean localisation economies range of 0.03 – 0.20 (mean value of 0.11). For the US, he found a localisation elasticity range of 0.09 – 0.45 with a mean value of 0.19.

Using 1977 data on the food processing industry within 174 Standard Metropolitan Statistical Areas in the US, Sveikauskas et al. (1988) concluded that economies of urban agglomeration clearly exist. They estimated economies of scale of 1.2 percent – i.e. a doubling of input increases output by an additional 1.2%.

Ciccone and Hall (1996) estimated the agglomeration effects for 50 States in the US and the District of Columbia using econometric analysis based on two simple models of spatial agglomeration – one based on spatial externalities and the other on non-tradable inputs produced with increasing returns to scale. Their work found that doubling the employment density increases average labour productivity by 6%. Ciccone (2002) estimated the agglomeration effects for several European countries using the same approach as Ciccone and Hall (1996). He estimated a productivity elasticity value of 0.045 between labour productivity and employment concentration. This, he highlighted, is slightly smaller than the agglomeration effects in the US based on the work of Ciccone and Hall (1996).

Utilising plant level data on productivity for 1972 – 1992 from the US which covers 742 counties in 317 metropolitan areas, Henderson (2003) derived a localisation elasticity range of 0.012 – 0.080 with a mean value of 0.03.

Rosenthal and Strange (2004) have surveyed the research literature on the relationship between city size / concentration and productivity. They found evidence that suggests productivity elasticity values in the range of 0.04 and 0.11. Based on this range of productivity elasticities, they estimated that doubling the concentration of a city (measured in terms of employment or population) could lead to an additional increase in the city's productivity of between 3% ($=2^{0.04} – 1$) to 8% ($=2^{0.11} – 1$)[17].

Venables and Rice (2004) used sub-regional data to analyse the spatial variation in income and productivity. They estimated an agglomeration elasticity of 0.05 which means that doubling the population of working age proximate to an area raises the productivity of the area by 3.5% ($=2^{0.05} – 1$). This is within the range estimated by Rosenthal and Strange (2004). Venables and Rice (2004) also suggested that 10% reduction in journey times to work is associated with a 1.12% increase in productivity. Their study also estimated that increasing the size of the working population located 80 minutes and beyond will have no effect on the local employment centre's productivity.

[17] Various studies (e.g. Graham and Van Dender, 2009, Rosenthal and Strange, 2004) have suggested this method of estimation to provide a discrete approximation of the productivity gains due to large changes in the economic mass. For minuscule changes in the employment such as in this research, the productivity elasticities are interpreted directly – i.e. a 1% change in employment is associated with a x% change in productivity gain for an elasticity value of x. This is discussed further in Chapter 9 – Section 9.3.1.1.

Melo et al. (2009) synthesized the results of 729 elasticities of agglomeration economies, taken from 34 separate studies. Their comparative analysis estimated a central productivity elasticity value of 0.06 which suggests that doubling the city size increases its urban productivity by 4.2% ($=2^{0.06} - 1$). This is consistent with the findings of Rosenthal and Strange (2004). Melo et al. (2009) also found that service industries have considerably larger benefits from agglomeration; they estimated that the elasticity for service industries is about 8 percentage points than the aggregate economy. This finding of Melo et al. (2009) suggests that the productivity gains from urban agglomeration for Melbourne CBD may be higher than the 3% to 8% identified by Rosenthal and Strange (2004).

Graham (2009) used data record on companies from FAME (Financial Analysis Made Easy) for the period of 1995 to 2002. Using a similar Translog Production Function approach as his earlier work, Graham (2009) estimated a weighted average localisation elasticity of 0.03 and 0.01 for manufacturing and services industries respectively. The mean urbanisation elasticities derived by him for manufacturing and services industries are 0.07 and 0.19 respectively.

2.6.4.1 Assessment

Table 2.7 presents a synthesis of the above studies. Overall, these studies found that increases in agglomeration have a positive impact on urban productivity. These studies reported a consistent productivity elasticity range of 0.04 and 0.11 which suggests that doubling the city size / concentration increases urban productivity by an amount that ranges from 3% - 8%. Having said so, these empirical studies have generally considered a region much larger than the Central Business District (CBD) which is the case study of this research. These regions are likely to have more manufacturing industries as compared to the CBD where the economy is more knowledge-based.

Using the agglomeration elasticities derived by Graham (2006b) and the CBD employment from the Census of Land Use and Employment (City of Melbourne, 2006), a weighted agglomeration elasticity of 0.216 is estimated for Melbourne CBD. This 0.216 elasticity value is about 4 times higher than average elasticity of 0.052 estimated by Graham (2006b) for manufacturing industries. Based on the work of Graham (2007a), this 0.216 elasticity suggests that doubling the employment densities accessible to Melbourne CBD could potentially raise its productivity by more than 20%. Melo et al. (2009) also concluded that the service sectors gain considerably larger benefits from agglomeration as compared to manufacturing sectors. It is therefore reasonable to expect the agglomeration effects associated with transport investment to have greater impact on the CBD's productivity. This means that the doubling of employment size of the CBD may increase its urban productivity by an additional amount closer to the upper limit of 8% or even higher than 8% suggested by past studies.

Table 2.7: Synthesis of studies that made use of spatial data and density measures to estimate agglomeration economies

s/no.	Study	Study Approach	Data Used	Findings
1	Aberg (1973)	Econometric analysis based on Cobb Douglas output per worker production function.	Cross-sectional data on manufacturing industries in Sweden from 1965 – 1968.	Aberg (1973) estimated an elasticity of productivity with regard to population density of 0.02.
2	Shefer (1973)	Econometric analysis based on CES output per worker production function.	Output, capital and labour data from the US two-digit manufacturing industries in SMSAs in 1958 and 1963.	Shefer (1973) concluded that localisation and urbanisation economies do exist in the manufacturing industries located in metropolitan areas. However, he found that the former varies widely across the industries. On the other hand, he estimated the rate of returns of urbanisaton economies to urban scale to be approximately 0.20.
3	Kawashima (1975)	Econometric analysis based on Cobb Douglas output per worker production function.	Output, capital and labour data from the US three-digit manufacturing industries in SMSAs in 1958 and 1967.	Kawashima (1975) estimated a population elasticity of 0.20. He also estimated that the optimal urban population size to be about 5.95 million.
4	Sveikauskas (1975)	Econometric analysis based on CES output per worker production function.	Output, capital and labour data from the US two-digit manufacturing industries in SMSAs in 1967.	Sveikauskas (1975) estimated that a doubling of city size is associated with a 5.98 percent increase in labour productivity.
5	Segal (1976)	Econometric analysis based on Cobb Douglas output per worker production function.	1967 data on employment and private capital for 58 SMSAs in the US. The employment data used include labour quality which was measured in terms of education level, age, percentage of those employed who were women and percentage of those employed who were white.	Segal (1976) concluded that SMSA with a population larger than 2 million or more has a return to factors that is 8% higher than the remaining SMSAs.
6	Fogarty and Garofalo (1978) (cited in Eberts and McMillen, 1999)	Econometric analysis based on CES output per worker production function.	Output, capital and labour data from the US manufacturing industries in SMSAs.	Fogarty and Garofalo (1978) estimated that a productivity elasticity of 0.10.
7	Moomaw (1981)	Econometric analysis based on Cobb Douglas output per worker production function.	Same data as Segal (1976).	Moomaw (1981) derived a productivity elasticity of 0.027 with respect to population size.

Table 2.7: Synthesis of studies that made use of spatial data and density measures to estimate agglomeration economies (con't)

s/no.	Study	Study Approach	Data Used	Findings
8	Nakamura (1985)	Translog specification of production function with labour share equation.	1979 private capital and employment for two-digit manufacturing for cities in Japan.	Nakamura (1985) estimated that the localisation economies increase by 4.45% with every doubling of population. He also derived an elasticity of 0.0336 for urbanisation economies with respect to population size. He concluded that, as a whole, the effects of localisation economies are more significant than urbanisation economies.
9	Tabuchi (1986)	Econometric analysis based on CES output per worker production function.	1980 private capital and employment for two-digit manufacturing for cities in Japan.	Tabuchi (1986) estimated that labour productivity increases by 4.3% with every doubling of population density i.e. productivity elasticity of 0.043.
10	Henderson (1986)	Econometric analysis based on a translog production function.	The US 1972 Census of Manufacturing- the basic sample covers 238 SMSAs. For Brazil, the primary data source is the 1970 Industrial Census.	Henderson (1986) found weak evidence of urbanisation economies (-0.021 to 0.177, with a mean value of 0.03). However, he estimated a 0.03 – 0.20 (mean value of 0.11) range for localisation economies for Brazil. For the US, he estimated a mean localisation value of 0.19.
11	Sveikauskas et al. (1988)	Econometric analysis based on a translog production function.	1977 data on the food processing industry within 174 SMSAs – data examined included employment, capital stock, material price and a quantitative measure of proximity to natural resources.	Sveikauskas et al. (1988) concluded that economies of urban agglomeration clearly exist. They estimated an economies of scale of 1.2 percent – i.e. a doubling of input increases output by an additional 1.2%.
12	Ciccone and Hall (1996)	Econometric analysis based on two different models – one based on local geographical externalities and the other on the diversity of local intermediate goods where spatial density results in aggregate increasing returns to scale.	1988 data on gross state output for 50 states in the US and District of Columbia.	Ciccone and Hall (1996) found that doubling the employment density increases average labour productivity by 6%. This suggests a productivity elasticity of 0.06.
13	Ciccone (2002)	Econometric analysis based on two simple model of spatial agglomeration – one based on spatial externalities and the other on non-tradable inputs produced with increasing returns to scale.	Data on value added at factor costs and salaried employment at regional level for Germany, Italy, France, Spain and the UK.	Ciccone's (2002) work suggested that agglomeration effects in the European countries examined are only slightly smaller than the agglomeration effects in the US. He estimated an average elasticity of labour productivity with respect to employment density of 0.045.

Table 2.7: Synthesis of studies that made use of spatial data and density measures to estimate agglomeration economies (con't)

s/no.	Study	Study Approach	Data Used	Findings
14	Henderson (2003)	Econometric analysis based on a translog production function.	Plant level data on productivity for 1972 – 1992 from the LRD of the Census Bureau which covers 742 counties in 317 metropolitan areas.	Henderson (2003) estimated a mean localization elasticity of 0.03.
15	Rosenthal and Strange (2004)	Reviewed research literature on the relationship between city size / density and productivity.	Research literature that were drawn largely from the US.	Rosenthal and Strange (2004) found evidence that suggests agglomeration elasticity in the range of 0.04 - 0.11. This means doubling the spatial mass that an area accesses increases its productivity by 3%- 8%.
16	Venables and Rice (2004)	Econometric investigation.	UK NUTS 3 sub-region data on average income per worker.	Venables and Rice (2004) estimated that an agglomeration elasticity of 0.05 which means that doubling the population of working age proximate to an area raises the productivity of the area by 3.5%. Venables and Rice (2004) also suggested that 10% reduction in journey times to work is associated with a 1.12% increase in productivity. Their study also estimated that increasing the size of the working population located 80 minutes and beyond will have no effect on the local employment centre's productivity.
17	Graham (2005, 2006b, 2007b)	Econometric analysis using Translog production function.	The data on the output of each firm, the total cost of production, the number of employees, an estimate of the capital assets and the average wage per employee of registered UK companies over the period of 1995 – 2003.	Graham (2005, 2006b, 2007b) suggested that transport investment can increase effective employment densities which can offer the opportunity for higher productivity. He estimated an average elasticity of agglomeration economies on productivity for manufacturing industries to be 0.052 while that for services industries to be 0.020.
18	Melo et al. (2009)	Comparative assessment of elasticities of agglomeration economies taken from 34 separate studies.	729 elasticities of agglomeration economies from 34 separate studies.	Based on their comparative analysis, they estimated a central elasticity value of 0.06 which suggests that the doubling of urban size increases productivity by 4.2%. This is consistent with the work of Rosenthal and Strange (2004).
19	Graham (2009)	Econometric analysis using Translog production function.	Cross-sectional data of firms from FAME data set (Financial Analysis Made Easy) for the period 1995 – 2002.	Graham (2009) estimated a weighted average localisation elasticity of 0.03 and 0.01 for manufacturing and services industries respectively. The mean urbanisation elasticities derived by him for manufacturing and services industries are 0.07 and 0.19 respectively.

2.6.5 Studies that used CGE Models to estimate the Wider Economic Impacts of Major Transport Infrastructure

Apart from the traditional use of econometric analysis using production functions, a recent development in transport economics is the use of CGE models to estimate the wider economic impacts of transport infrastructure (Vickerman, 2007b, Brocker, 2004). While the use of CGE models to estimate the wider economic benefits of transport investments only started in the latter half of the 1990s, they had been used considerably to evaluate transport construction projects much earlier (Gwee et al., 2010).

A spatial dimension is the heart of transport analysis in CGE modelling and CGE modellers of transport problems have taken various approaches to introduce this dimension into their modelling (Gwee and Madden, 2010). A regional dimension was first introduced into CGE modelling over thirty years ago in the early stages of CGE's development (Dixon and Rimmer, 2010). Initially, this involved top-down modelling in which the spatial dimension was somewhat limited, with commodities being divided into those whose sales were restricted to the local regional market and those which were traded nationally with regions maintaining fixed shares of the national market for individual commodities (Dixon et al., 1978)[18]. Madden and Dixon (1990) used this top-down approach to examine a proposed very fast train between the Australian cities of Melbourne and Sydney. While they were able to decompose the results to the regional level for the construction phase, they were not able to undertake a proper decomposition of the effects of the cost-savings from the more efficient transport system to the regional level.

[18] The fixed regional shares for national industries restriction has been removed in more recent top-down modelling (Dixon et al., 2007).

While “top-down” models are still used, “bottom-up” regional models have taken over as the main form of CGE modelling for policy analysis in Australia since the late 1990s (Madden and Giesecke, 1999). The development of a bottom-up multiregional CGE model in the early 1980s allowed for the possibility of supply-side shocks to be imposed at the regional level (Liew, 1981, 1984a and 1984b)[19]. Liew’s (1981) 6-region model of Australia (MRSMAE), however, did not contain technology variables, nor did it contain an explicit modelling of transport (or any other) margins[20]. The latter meant that there was no relationship in terms of geographical relationship between the regions.

In the mid-1980s, Madden (1985b) developed a modelling approach that had the advantages of “bottom-up” modelling without the problems faced by Liew (1981, 1984a, 1984b). In his approach, Madden (1985a, 1989) limited the number of regions in the model to two and incorporated technological variables as well as regionally-supplied margins for spreading interstate exports and imports between the region of focus and the rest of Australia. Madden’s (1985a, 1989) work led to the eventual construction of the multi-regional CGE model, FEDERAL, which up to recent times has been a two-region model (Madden, 1990). Madden (1990) chose a two-region structure for FEDERAL so as to ease the computational burden for the model which was aimed mainly at exploring fiscal federalism issues and consequently contained very detailed modelling of two-tiers of government.[21]

[19] Madden et al. (1983) demonstrated that demand-side shocks could be successfully imposed in a top-down framework at the regional level. Higgs et al. (1988) developed a hybrid top-down/bottom-up method which allowed supply-side shocks to a number of regionally-defined industries within the national model.

[20] In CGE terminology, margins refer to services (e.g. transport, wholesale and retail trade) that must also be purchased in order for goods to reach a customer located in a particular region. See Section 8.2.2.7 for more details.

[21] For examples of FEDERAL applications on fiscal federalism issues, see Madden (1993), Dixon et al. (1993) and Giesecke and Madden (1997). In the 1990s FEDERAL formed the starting point for the dynamic CGE model, FEDERAL-F which introduced many features of the national CGE model MONASH (Dixon and Rimmer, 2002) to enable historical modelling and forecasting (Giesecke, 2002, 2003). FEDERAL-F also introduced: a dynamic version of FEDERAL’s treatment of out-of-region ownership of capital; and a lagged adjustment handling of interstate migration developed from the Jones and Whalley (1989) formulation.

Buckley (1992) and Wigle (1992) developed multiregional CGE models with a specific transport focus. Buckley's (1992) 5-sector model which covered three regions of the United States, had similar features with Jones and Whalley's (1989) 6-region Canadian model, in particular, the inclusion of transport and wholesale margin services on direct flows being supplied by the origin and destination regions respectively. Wigle's (1992) 7-region (6 Canadian and the US) 13-sector model aimed to capture a spatial dimension by introducing distance-related transport margins. As his focus was on the importance of transport costs in trade restrictions, he kept the rest of his model simple - goods were being produced by a single technology and outputs distributed according to a production possibility frontier.

By the early 1990s, Dixon et al. (1993) realised that a comprehensive study of Federal and State public finance issues required a model which was medium term, dynamic and explicitly treated all states and territories. This led to the construction of the Monash Multiregional Forecasting model (MMRF) (Navqi and Peter, 1996). MMRF shared a similar structure to the FEDERAL model, both being based upon the ORANI principles (Dixon et al., 1982). The MMRF, which covered eight regions of Australia, provided an operational model which allowed policy issues relating to all or several Australian states and territories to be examined at the same time (Adams et al., 2002).

Over the last 15 years or so, MMRF has been used in hundreds of studies and is today the standard model in Australia for regional analysis. The MMRF model has also provided the template for multiregional models of other countries, most notably the B-MARIA model of Brazil (Haddad, 1999). Examples of MMRF applications on transport projects are the evaluation of the economic effects of a number of freeway construction projects in the Australian state of Queensland (Madden, 2006, 2008)[22]. Current versions of MMRF are year-on-year dynamic, and transport projects are typically modelled over a time horizon of over 40 years (e.g. a construction phase of 5 years and an operating phase of 10 years[23].

[22] MMRF transport applications have not been confined to just infrastructure issues. MMRF has been used to examine other transport related questions, such as port and airport efficiency, freight subsidy schemes, and deregulation of the road transport industry (e.g. Madden, 2003). Similarly FEDERAL has also been used to address such questions (e.g. Madden et al. (2008) used FEDERAL to examine the effects of a set of reforms for the Tasmanian transport industry).

[23] MMRF has been the subject of continual development over the past decade and a half, including the upgrading of the model to include many of the features of the national dynamic CGE model, MONASH. Other additions include extensive greenhouse features, such as greenhouse gas emissions by fuel, fuel user and region of fuel use (Adams, 2007), road-rail substitution.

In the latter half of the 1990s, the advent of the New Economic Geography saw a new development in spatial CGE modelling. Notable is the work of Brocker (1995, 1996, 2002) who introduced monopolistic competition with agglomeration economies. Similar to Brocker, the RAEM model of the Netherlands (Oosterhaven, et al., 2001 and Thissen, 2004) achieves agglomeration economies via the Dixit-Stiglitz love-of-variety framework[24]. However, unlike Brocker, the RAEM does not use the "iceberg" approach[25] to freight transport, rather treating transport as a mark-up on the flow of direct goods[26]. Of particular relevance to this research is the introduction of travel costs into RAEM, both for commuting and shopping. The modelling of regional labour markets is based on search theory, both for employers and for job-seekers who look for jobs in the various regions. Mismatches can result in regional unemployment, and in the long-run worker utility is equalised across regions.

2.6.5.1 Applications of CGE Modelling to estimate the Wider Economic Impacts of Major Transport Infrastructure

Given that the use of CGE models to estimate wider economic benefits is relatively new, a review of past studies showed only the following few published applications of CGE modelling in economic appraisals of large transport infrastructure projects:

- Transport improvements for the Scoresby corridor in metropolitan Melbourne, Australia (Sinclair Knight Merz, 1998)
- Tokai-Hokuriku expressway proposal for Chubu region, Japan (Miyagi, 1998, 2001)
- Maglev proposal connecting Schiphol Airport and Groningen, Holland (Elhorst et al., 2004, Oosterhaven and Elhorst, 2003)
- Trans-European Transport Network for commodity trade (Brocker, 2004).

[24] Dixit-Stiglitz is a monopolistic competition framework where consumers love variety and firms have fixed requirements for limited productive resources; love of variety is captured by a CES utility function that is symmetric in a bundle of differentiated products and each firm is assumed to be a negligible actor in that it has no impact on overall market conditions (Fujita et al., 1999).

[25] The "iceberg" approach models transportation as a costly activity that uses the transported good itself – a certain fraction of the good melts on the way (hence the name "iceberg") (Ottaviano et al., 2002).

[26] Others to introduce agglomeration economies into a model (B-MARIA) with explicit freight margins are Haddad and Hewings (2005). They do so via non-constant returns production functions.

These studies used the CGE modelling approach to estimate the wider economic benefits associated with these large transport investments; they however did not specifically estimate the associated agglomeration benefits. The evaluation process of these studies can be generalised into the following three steps.

1. Generate the expected travel time or generalised travel cost before and after the proposed changes in the transport network (or with and without the proposed transport investment) using a standard four-step transport model.
2. Feed the outcome of the transport model as an input into the CGE model so as to simulate the impact of these changes in travel time on the productivity of the various industries and their overall effect on the region's economy.
3. The economic effects arising from the implementation of the proposed transport improvement can then be estimated by measuring the consumer's benefits in the before-after comparison.
   (Elhorst et al., 2004, Miyagi, 2001).

These studies found the following varying estimates of wider economic benefits.

- Scoresby Transport Corridor Environment Effects Statement –
  Sinclair Knight Merz (1998) used NIEIR's IMP model (Brain, 1977) for this study. They estimated that the proposed transport improvements would result in wider economic benefits of about A$200 million per year to the Victorian Gross Product in 2025.
- Tokai-Hokuriku expressway proposal –
  Miyagi (1998, 2001) used the MH CGE model which was developed by Miyagi and Honbu for this work. His evaluation indicated that the proposed US$14 billion Tokai-Hokuriku expressway will generate annual wider economic benefits in the order of US$1.1 billion.
- Maglev proposal connecting Schiphol Airport and Groningen –
  Using the Dutch RAEM model, Elhorst et al. (2004) and Oosterhaven and Elhorst (2003) estimated the wider economic benefits of the Maglev proposal to vary from -1% to +39% of the direct transport benefits, depending on the regions connected and the general condition of the economy.
- Trans-European Transport Network –
  Brocker's (2004) assessment suggested that the Trans-European transport network as a whole will have positive impact on some regions and negative impacts on others and that the overall contribution of such wider economic impacts is expected to be relatively modest (typically to be less than 2% of regional GRP).

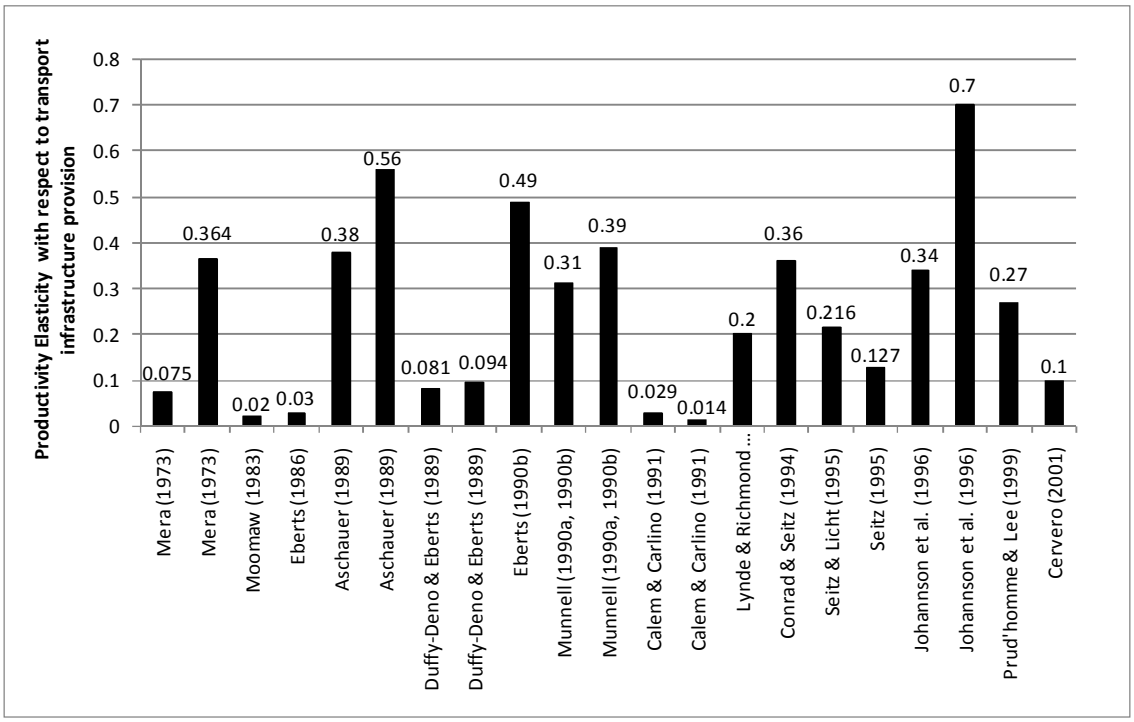
Clearly this is a wide range of outcomes. It is unclear if this is due to the diverse nature of the projects, or the different nature of the regions examined or if the type of models used and the method of applications had any implication on the outcomes. It is apparent that there is much room to address these knowledge gaps in future research.

2.7 Synthesis and Knowledge Gaps

The literature review has demonstrated that there is no consensus concerning the methods used to estimate the agglomeration benefits nor the scale of such potential benefits.

Section 2.6 highlighted a diverse range of findings about the effects of transport projects on economic productivity. A significantly larger number of studies found a positive connection between public capital stock (which included transport infrastructure) and economic productivity. This may suggest that agglomeration benefits associated with transport investments are valid. Interestingly, no studies to date have suggested that the provision of transport infrastructure would impact economic productivity negatively. This further supports the earlier proposition.

The productivity impact estimated using public capital stock may not be totally attributable to agglomeration effects associated with transport projects since the direction of causality is unclear - Graham (2005) explained that regions with higher productivity tend to have higher income and are able to spend more on public infrastructure; in other words, the role of public infrastructure from the production and costs function analyses are inconclusive. Nonetheless, a synthesis of evidence from these studies suggests that agglomeration effects associated with transport improvements might be substantial. As shown in Figure 2.3, these studies estimated that a 1% increase in transport infrastructure provision could lead to an increase from 0.014% – 0.70% in economic productivity. This is clearly a wide range of elasticity.



Source: Developed from Mera (1973), Moomaw (1983), Eberts (1986), Aschauer (1989), Duffy-Deno (1989), Eberts (1990b), Munnell (1990a, 1990b), Calem and Carlino (1991), Lynde and Richmond (1992, 1993), Conrad and Seitz (1994), Seitz and Licht (1995), Seitz (1995), Prud'homme and Lee (1999) and Cervero (2001)

Figure 2.3: Synthesis of values of elasticities between productivity and transport infrastructure provision - previous studies[27]

Recent studies have argued that transport improvements can improve the proximity between firms and the labour market which in turn increases employment densities and hence productivity. Based on a synthesis of their findings, it is estimated that a doubling of employment size or concentration could potentially increase the urban productivity of a region by 3% - 8%. Having said so, the work of Graham (2005, 2006b, 2007b) and Melo et al. (2009) suggest that the doubling of employment size of the CBD given its higher concentration of knowledge-based sectors, may increase its urban productivity by an amount higher than 8%. There is therefore a knowledge gap pertaining to the plausible economic value of agglomeration effects associated with transport improvements in particular urban rail serving city centers.

[27] Figure 2.3 shows the distribution of elasticities between productivity and transport infrastructure provision estimated from past studies. It does not include the productivity elasticities estimated by the studies presented in Table 2.7.

In addition, earlier studies have largely focused on estimating the productivity elasticity of transport infrastructural provision in general rather than that associated with a specific mode such as urban passenger rail projects. The larger carrying capacity of these systems suggests that the agglomeration benefits associated with rail may be potentially higher than for other transport investment. As urban rail projects are generally seen as an important element of successful cities (as highlighted in various work such as Hazel and Parry (2004)), there is therefore some motivation to better understand the agglomeration economies specifically associated with urban passenger rail.

This review of past studies also showed that econometric analysis via the application of Production Functions using regression models is the most common approach used in earlier studies of agglomeration economies. The wide disparity in the values of output elasticities between productivity and transport infrastructure (as shown in Figure 2.3) however suggests that there is room to improve the method to estimate such benefits. In addition, the literature review also highlighted that recent development in the field of transport economics involves the use of CGE modelling technique to estimate the wider economic benefits of transport investments (Vickerman, 2007b, Brocker, 2004). While there was limited use of the CGE modelling technique to estimate wider economic benefits, no published work regarding agglomeration benefits associated with urban passenger rail projects has been found. There is therefore a clear case to improve the methodologies to estimate such agglomeration effects using the CGE modelling approach.

2.8 Summary

Agglomeration benefits in production are defined as the increase in productivity, creativity and synergy amongst firms due to an increase in the absolute size or concentration of employment and population (Dft, 2006, NZTA, 2008). The concept underlying the agglomeration effects of transport investments is that they have positive effects on the concentration of economic activities within a certain geographical and travel time space; this will lead to higher productivity and generate additional economic benefits which are today not included in CBA (Graham, 2005, 2006b). To illustrate how urban passenger rail investments could lead to an increase in productivity, a schematic model of the theoretical linkages between transport investment and agglomeration economies based on literature review was developed for the purpose of this research (see Figure 2.2).

As illustrated in the schematic model, an improvement in the transport network is expected to improve the mutual proximity between people and firms and reduce the generalised cost of travel; this will help to broaden access to the labour market, expand the market for goods and services as well as improve the accessibility to development sites. These effects will in turn facilitate the creation of a larger, more specialise labour and client market, forge a more complementary and competitive business environment and promote knowledge interaction which is expected to increase the individual firm's productivity and improve the region's economy collectively.

The literature review highlighted the diverse and conflicting findings about the effects of transport projects on economic productivity from earlier work. However, a significantly larger numbers of studies found a positive connection between transport infrastructure provision and productivity which may suggest that agglomeration benefits associated with transport investments are valid. The fact that there are no studies to date that suggested that the provision of transport infrastructure would impact urban productivity negatively further supports this proposition.

A synthesis of evidence from previous studies suggested that agglomeration effects associated with urban rail projects might be significant. However, the wide range of estimated productivity elasticity values clearly suggests that there is a knowledge gap pertaining to the plausible range of its economic value. In addition, previous studies have mainly focused on estimating the productivity elasticity of transport infrastructure provision in general rather than that associated with a specific mode such as urban passenger rail projects. As urban rail projects are generally seen as an important element of successful cities, there is some motivation to better understand the agglomeration economies specifically associated with them.

The literature review also revealed that the application of econometric analysis via the production function approach may not be the most comprehensive method to estimate agglomeration benefits albeit being popularly used in earlier studies. Recent development in the field of agglomeration benefits suggests that CGE modelling approach may offer a more comprehensive platform for estimating the productivity impact of agglomeration economies associated with urban passenger rail projects.

CHAPTER 3

Research Methodology

3.1 Introduction

This chapter presents the research methodology for this research. The research methodology consists of a framework of primary and secondary research as well as a modelling approach involving the use of a transport model and an economic Computable General Equilibrium (CGE) model. Melbourne Central Business District (CBD) has been adopted as the case study for this research to explore agglomeration effects associated with urban rail.

The chapter is structured in the following sequence.

- **Section 3.2 -** **Methodological Concept** presents the concept underlying the research methodology.
- **Section 3.3 -** **Methodological Details** explains each key component of the method.
- **Section 3.4 -** **Summary** concludes the chapter.

3.2 Methodological Concept

The research methodology is shown in Figure 3.1. Conceptually, the research methodology consists of the following five key components (represented by the oval shapes shaded in black).

1. A secondary research and data analyses[1] framework to gather evidence to support the other components of the research methodology and benchmark their findings.
2. A transport modelling approach using the Melbourne Multi-modal Integrated Transport Model (MITM) from Department of Transport (DOT), Victoria to understand how the AM peak travel time and generalised cost of automobile trips into Melbourne CBD would change under various levels of urban rail capacity constraint i.e. rail capacity demand exceeds provision.
3. A web-based survey to gather feedback from Melbourne CBD employers to understand how they perceived rising rail congestion would affect their businesses in the CBD.
4. A CGE experimental modelling approach using the TERM model[2] from the Centre of Policy Studies (CoPs), Monash University to estimate the economic value of the agglomeration effects associated with urban rail projects.
5. A comparative assessment of results with the agglomeration estimates from other approaches in particular the method adopted by the UK Department of Transport (DfT) (2009) and the New Zealand Transport Agency (NZTA) (2008) – this method is referred to in this thesis as **PETE** since it essentially measures the **P**roximity between **E**mployees **T**o **E**mployers[3].

[1] For presentation purposes, the secondary research and data analysis elements which are carried out as part of another key research component are shown as shaded rectangles in Figure 3.1 – please refer to legend. The major secondary data analysis component represented as a black oval shape in Figure 3.1 refers to the assessment using data from international cities – see item 4 of Section 3.3.1 for more details.

[2] As highlighted in Chapter One, TERM stands for The Enormous Regional Model. This is the name given by its creator in the Centre of Policy Studies, Monash University (Horridge et al., 2005).

[3] PETE is a method used in this research to estimate the productivity shocks (for input into TERM) and the agglomeration diseconomies. It is, however, not a key research component. This explains why it is represented by an oval-shape but not highlighted in black.

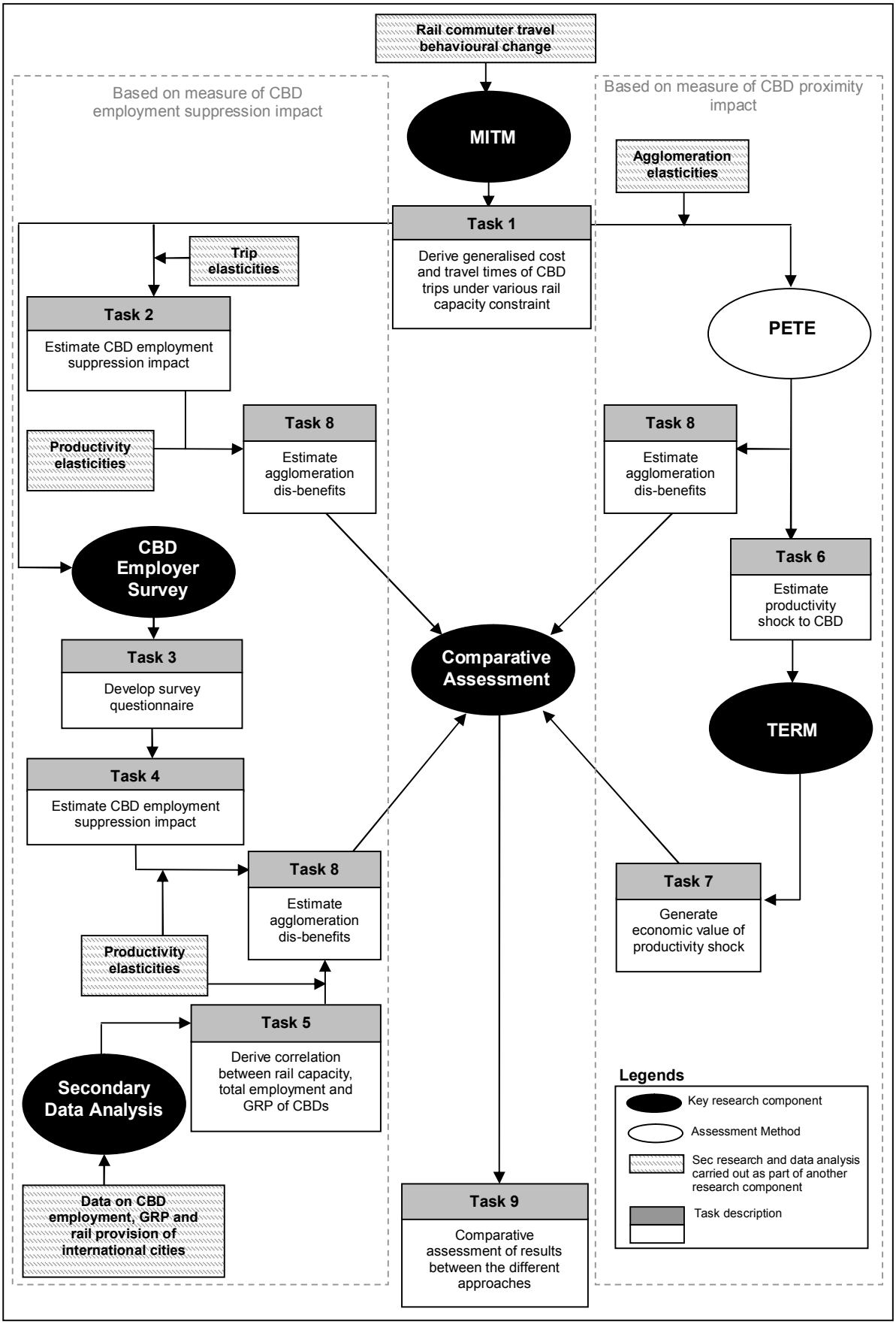


Figure 3.1: Research methodology

The literature review (Section 2.5.1) has suggested that there is room to improve the methodology for estimating agglomeration effects in transport projects. This study therefore developed the above framework that integrates various research components. The aim is to use a wide array of tools to explore the agglomeration effects in urban rail from various approaches.

The research methodology explores agglomeration economies in urban rail through the following two measures associated with an urban rail capacity constraint - as explained in Chapter 1, this research defines an urban rail capacity constraint as a situation where rail demand exceeds the rail capacity provided.

1. The potential employment suppression impact
2. The potential change in the proximity between CBD firms and workers.

The 1st measure of agglomeration effects is estimated by various approaches represented by the research tasks shown on the left-hand side of Figure 3.1. The research tasks shown on the right-hand side of Figure 3.1 are approaches to estimate the 2nd measure of agglomeration effects.

The fundamental assumption underlying the research methodology is that the urban passenger rail system serving Melbourne CBD is an enabler of the CBD's economic growth. Therefore, if urban rail capacity is constrained, agglomeration diseconomies due to the corresponding increase in traffic congestion would set in. This would result in poorer accessibility of the CBD which may affect the proximity between the employees and CBD firms. The rising congestion may also cause some CBD employers to relocate or give up their work trips and hence employment in the CBD. This would lead to a decrease in the total number of employees working in Melbourne CBD. According to the theory of agglomeration, this drop in the accessibility and employment concentration of the CBD will result in an overall deterioration of its productivity[4]. The economic value of this urban dis-agglomeration will provide a mirror indication of the agglomeration benefits associated with the expansion of urban passenger rail provision to ease a capacity constraint. A major motivation for this approach is overcrowding of Melbourne CBD rail services which has occurred over the last 5 years. An exploration of affected use where rail capacity constraints continue may inform policy to address these problems.

[4] These effects are different from the labour market effects mentioned in Section 2.2 which refers to the direct impact to a regions' economy due to the changes in the total labour force participation. The reduction in productivity indicated here refers to the lowering of the CBD's productivity over and above that of the labour market effects.

The scope of each task (Figure 3.1) is as follow.

- **Task 1 -** Benchmark how the AM peak travel times and generalised cost of travel into Melbourne CBD may change under different levels of urban rail capacity constraint using MITM and information from secondary research.
- **Task 2 -** Analyse and establish how urban passenger rail capacity constraint may influence the CBD's labour supply using the findings from task (1) and trip elasticity values from secondary research.
- **Task 3 -** Develop a survey questionnaire using the output from task (1) to solicit information from CBD employers on the potential impact of urban rail congestion on firms' business costs, labour demand and location decisions within Melbourne CBD.
- **Task 4 -** Analyse the survey results to establish the potential impact of urban rail congestion on the CBD's employment concentration (i.e. the number of workers per unit area).
- **Task 5 -** Investigate the relationship between employment size, Gross Regional Product (GRP) and urban rail capacity provision of CBDs by analysing secondary data from international and Australian cities to benchmark the findings from task (2), (4) and (7).
- **Task 6 -** Derive a range of productivity shocks[5] associated with an urban rail constraint on Melbourne CBD using the findings from task (1) and agglomeration elasticities via the PETE method.
- **Task 7 -** Estimate the value of the productivity shocks to the CBD's economy by inputting the output from Task (6) into the TERM model.
- **Task 8 -** Estimate the potential agglomeration dis-benefits associated with an urban rail capacity constraint using (i) employment suppression impacts estimated from task (2), (4) and (5) and productivity elasticities[6] from secondary research and (ii) output from task (1) and agglomeration elasticities via the PETE method.
- **Task 9 -** Compare the economic values of the agglomeration effects in urban rail estimated from tasks (7) and (8).

[5] In CGE terminology, the process of inputting any impact into the economic model so as to simulate its impact to the economy is known as a "shock" (Dixon et al., 2002a).

[6] As explained in Section 2.6.4 (page 52), productivity elasticity refers to the elasticity between labour productivity and employment concentration. This is not the same as the agglomeration elasticity estimated by Graham (2005, 2006b) which refers to the elasticity between urban productivity and the accessibility between workers and firms – see page 51 for definition.

This research methodology is broadly similar in concept to the approach for estimating agglomeration benefits advocated in the Transport Analysis Guide (Unit 3.5.14) of DfT (2009) and the Economic Evaluation Manual (Volume 1, Appendix A10) of NZTA (2008). These methods – referred to as PETE in this thesis – use outputs from transport modelling to estimate the generalised cost of travel between various origin-destination (O-D) pairs for scenarios with and without the proposed transport improvement. The changes in the generalised costs are then used to estimate the improvements in the effective employment densities between each O-D pair. The latter are finally used to estimate the total agglomeration impacts associated with the proposed transport improvement using agglomeration elasticity.

The methodology employed in this research also uses generalised cost of travel as a starting point. However, the key differences to the PETE method are as follows.

1. Apart from measuring the change in the accessibility between CBD firms and workers, this research also measures the agglomeration effects in urban rail by estimating the potential employment suppression impact associated with urban rail constraint. These are used with productivity elasticities to estimate agglomeration dis-benefits via a different approach.

2. This research uses a CGE model to estimate the economic value of agglomeration diseconomies associated with urban rail constraint rather than from agglomeration elasticities via the PETE method directly.

3.3 Methodological Details

This section presents the details of the five main research components highlighted in Section 3.1. Details of Melbourne CBD and its related travel issues as well as the justification to adopt it as the case study are presented in the next chapter.

This section is organised in the following order.

- **Section 3.3.1 - Secondary Research and Data Analyses** outlines the secondary research and data analyses carried out to support other components of this research.
- **Section 3.3.2 - Transport Modelling** presents the transport modelling approach that has been applied on MITM.
- **Section 3.3.3 - Melbourne CBD Employer** describes the framework of the Melbourne CBD employer survey.
- **Section 3.3.4 - Computable General Equilibrium Modelling** explains the experimental CGE modelling approach.
- **Section 3.3.5 - Comparative Assessment** outlines the comparative assessment framework.

3.3.1 Secondary Research and Data Analyses

A series of secondary research and data analyses were undertaken for a range of purposes including:

- determining the status of rail capacity constraint facing Melbourne CBD today and in the next few years so as to correctly interpret the outputs of transport and CGE modelling
- investigating how rail commuters' travel behaviour may change in a situation of rail capacity constraint so as to provide informed inputs to MITM modelling
- exploring how CBD employment concentration (i.e. the number of workers per unit area), GRP and rail capacity provision relate to each other in international and Australian cities.

The following secondary research and data analyses have been carried out.

1. **Benchmarking the current and future positions of the overall capacity of Melbourne Metropolitan train network**

   Secondary data pertaining to the urban rail capacity provision and utilisation from the DOT and the (now previous) rail operator, Connex Melbourne have been gathered and analysed for benchmarking purposes. The intention of this benchmarking exercise is to enable this research to interpret how the highway congestion status derived from MITM fits into the real world.

   In addition, the benchmarking would also enable this research to interpret how the CGE modelling results correlate with the actual rail capacity constraint situation. Details of the benchmarking exercise are presented in Section 4.4.3.

2. **MITM modelling**

   Secondary research was conducted prior to MITM modelling to understand how rail commuters' travel behaviour would change under circumstances of urban rail capacity constraint. Relevant information has been gathered from past survey studies on the social and economic benefits of transit systems, as well as from literature related to user behavioural change in the absence of transit.

   The understanding of how rail commuters' travel behaviour may change in a situation of a rail capacity constraint is necessary so that relevant modelling assumptions could be correctly set up in MITM. Further details are presented in Chapter 5.

3. **Potential trip and employment suppression impact of rail capacity constraint**

   In order to estimate the potential trip and employment suppression impacts associated with a rail capacity constraint, from MITM's output, trip elasticities with respect to the generalised cost of travel have been gathered from various sources via secondary research. Further details are presented in Chapter 5.

4. **Benchmarking CBD performance - correlation between employment concentration, urban productivity and rail provision**

   Secondary data analysis has been conducted using data from international and Australian cities to investigate the correlation between CBD employment size, GRP and rail capacity provision.

   This exercise is to assist in benchmarking the findings from the other components of this research. In addition, the secondary data analysis is one of the 3 approaches adopted in this study to estimate the potential employment suppression impact associated with an urban rail constraint. Details of the methodology employed and the findings are presented in Chapter 7.

   Secondary data analysis using data from several major Australian CBDs has also been carried out to justify how reasonable Melbourne CBD is as a case study for this research. Further details of this are presented in Section 4.6.

3.3.2 Transport Modelling

The fundamental assumption underlying the proposed study approach of this research is that the urban passenger rail system serving Melbourne CBD is an enabler of the CBD's economic growth. Any constraint on the rail capacity would not only affect the rail accessibility of the CBD, it will also impact its road accessibility as some of the rail commuters will be "forced-out" of the rail system and switch to other modes. Secondary research suggests that the majority of these affected rail users are likely to switch to private cars and to a much lesser extent, tram and buses as well as walking and cycling. This will lead to a surge in the volume of road traffic and increase traffic congestion which affects primarily the automobile users.

DOT's MITM has been used in this research to run an array of transport scenarios to illustrate how various degrees of rail accessibility constraint would affect the highway travel times into Melbourne CBD during the AM peak period of a typical weekday. The scenarios tested in MITM are not traffic forecasts of future years; they merely simulate how current (2006) travel times into Melbourne CBD on the existing highway network would be affected by various levels of rail congestion.

MITM's output serves the following three purposes.

1. To estimate the potential trip and labour supply suppression[7] impacts associated with urban rail capacity constraint – this is one of the 3 approaches adopted in this research to measure the potential employment suppression impact associated with an urban rail constraint. The labour supply suppression impact has been estimated using changes in the generalised cost of travel from MITM and trip elasticity values from secondary research.
2. To act as an input to the CBD employer survey (Chapter 6). In particular, to specify road congestion impacts of rail capacity constraint so that employers can better understand the potential impact of rail congestion on their businesses.
3. To act as an input to the PETE method for estimating the agglomeration dis-benefits and productivity shocks associated with urban rail constraint. The productivity shocks in turn act as an input to the TERM model (Chapter 8).

MITM modelling involves the manipulation of the AM peak hour highway demand matrix. Fundamentally, this comprises the following two processes.

1. Estimate the proportion of rail commuters who are expected to divert to the automobile (either as a car driver or passenger) after they are "forced-out" of the train system due to rail capacity constraint. The change in travel behaviour (or mode shift) of these rail commuters have been based on evidence gathered through secondary research.
2. Add the diverted rail-to-car trips to the base case highway demand matrix and perform a Highway Assignment run in MITM with the new highway demand matrix.

In this way, the scenario where the "forced-out" train commuters are "loaded" onto the highway network are simulated in MITM. The MITM modelling approach does not model those "forced-out" rail trips that may shift to the tram and bus. This is because secondary analysis suggests that these modes have ample capacity to absorb the diverted rail users; they are not modelled in MITM as they are not anticipated to be significantly affected. Further details regarding the transport modelling work that has been carried out, and the corresponding results, are presented in Chapter 5.

[7] While DfT (2006, page 20) commented that the measure of the changes in a city's employment to estimate agglomeration economies "do not necessarily suffice", this research uses this approach as one of the methods for comparative assessment purposes – see Section 3.3.5. This is to explore how the agglomeration economies estimated using this method compares with the approach adopted by DfT (2009) and NZTA (2008) which measures the proximity between workers and firms.

3.3.3 Melbourne CBD Employer Survey

The objective of the Melbourne CBD employer survey is to understand the potential impact that rail congestion may have on the CBD's labour demand. This primary data collection exercise is one of the 3 approaches used in this research to measure the potential employment suppression impact associated with dis-agglomeration effects in urban rail. The employer survey was conducted through the SurveyMonkey[8] platform.

To ensure that a respectable survey response rate is achieved, the survey questionnaire has been designed to include a series of multiple choice questions that could be completed within a time frame of 15 minutes - secondary research suggests that the overall response rate of participants is likely to deteriorate rapidly after 10-15 minutes (Richardson et al., 1995). The survey questionnaire was designed to gather inputs on the following three aspects of CBD businesses.

1. Details of firm (such as the industry the business belongs to) and employees (such as staff strength and mode of transport to work).
2. Firm's 'willingness-to-pay' (via increased remuneration) to retain or attract new staff for various degrees of traffic congestion.
3. Impact of traffic congestion on their future employment plans in the short term and their decision to continue to stay or leave the CBD should the traffic congestion worsen in the longer term.

Output from the earlier MITM traffic scenario testing was used as an input to the survey. In particular, hypothetical journey times to work in the CBD under different levels of rail capacity constraint were used to illustrate the impacts of rail congestion to the participants.

A direct telephone call invitation approach was adopted in the recruitment of employers for the survey. This approach was chosen as it enabled the CBD companies to be targeted directly at the shortest time and the lowest cost possible. The survey has been conducted in 2 stages:

- a pilot survey to test the opt-in process, clarity of questionnaire and user-friendliness of the questionnaire
- the main survey.

[8] SurveyMonkey is an on-line survey tool.

To comply with the ethical requirements of the Monash University Standing Committee on Ethics Research Involving Humans (SCERH), ethical approval for the survey was sought prior to the survey execution.

Further details of the survey, including the key results and corresponding analyses are presented in Chapter 6 of this thesis.

3.3.4 Computable General Equilibrium Modelling

A CGE experimental modelling approach using TERM was adopted in this study to explore how the dis-agglomeration effects associated with an urban rail constraint will impact the economy of Melbourne CBD and to test whether there might be any inter-regional flow-on effects. TERM is a new generation of ORANI-style models developed by the Centre of Policy Studies (CoPS), Monash University (Horridge et al., 2005).

To the best knowledge of the author, there is no published work to date regarding the use of CGE models to estimate agglomeration effects in urban passenger rail projects. This research has therefore experimented with various ways to simulate agglomeration effects in CGE modelling - this explains why this element of the methodology is termed as an experimental modelling approach. The modelling approach finally adopted in this research was to “shock” the variable in TERM which governs the primary input augmenting technical change so as to simulate the productivity impacts associated with agglomeration effects in urban rail.

The productivity shocks applied on TERM were estimated using the PETE method using the changes in the generalised costs of trips into the CBD under scenarios of rail capacity constraints (generated by the MITM) and agglomeration elasticities from DfT (2009) and NZTA (2008). Further details regarding the TERM model and the CGE modelling approach are presented in Chapter 8 of this thesis.

3.3.5 Comparative Assessment

The output from TERM has been compared with the economic values estimated based on the employment suppression impacts as well as the PETE approach to test the robustness and variability of alternative approaches. Further discussion on the comparative assessment of results is presented in Chapter 10 of this thesis.

3.4 Summary

This chapter presents the research methodology adopted in this research. The methodology consists of the following five main components.

1. A secondary research and data analyses framework to gather evidence to support the other components of the research methodology and benchmark their findings.
2. A MITM modelling approach to understand how the travel time and generalised cost of automobile trips into Melbourne CBD are likely to change under various levels of urban rail capacity constraint.
3. A web-based survey to gather feedback from Melbourne CBD employers to understand the potential impact that rail congestion may have on CBD employment.
4. A CGE modelling approach using the TERM model to estimate the economic value of the agglomeration effects associated with urban rail projects.
5. A comparative assessment of TERM's results with the other approaches in particular the PETE method.

The basic assumption underpinning the research methodology is that the urban passenger rail system serving Melbourne CBD is an enabler of the CBD's economic growth. Therefore, if the urban rail capacity serving the CBD is constrained, agglomeration diseconomies due to the corresponding increase in traffic congestion would set in. This would result in poorer accessibility of the CBD which may affect the proximity between the employees and CBD firms. The rising congestion may also cause some CBD employers to give up their employment in the CBD. This is likely to reduce the employment concentration (i.e. the number of workers per unit area) of Melbourne CBD. According to the theory of agglomeration, this drop in the accessibility and employment concentration of the CBD is envisaged to cause an overall reduction in the CBD's productivity. It is expected that the economic value of this urban dis-agglomeration will provide a mirror indication of the agglomeration benefits associated with new urban passenger rail provision.

Conceptually, the research methodology adopted in this research is broadly similar to the PETE method used by DfT (2009) and NZTA (2008). The key differences are that this research estimates the potential fall in the CBD's total employment as another measure of the dis-agglomeration effects in urban rail and uses a CGE modelling approach to estimate the economic value of the agglomeration effects associated with an urban rail capacity constraint.

CHAPTER 4

Case Study: Travel Issues to Melbourne Central Business District

4.1 Introduction

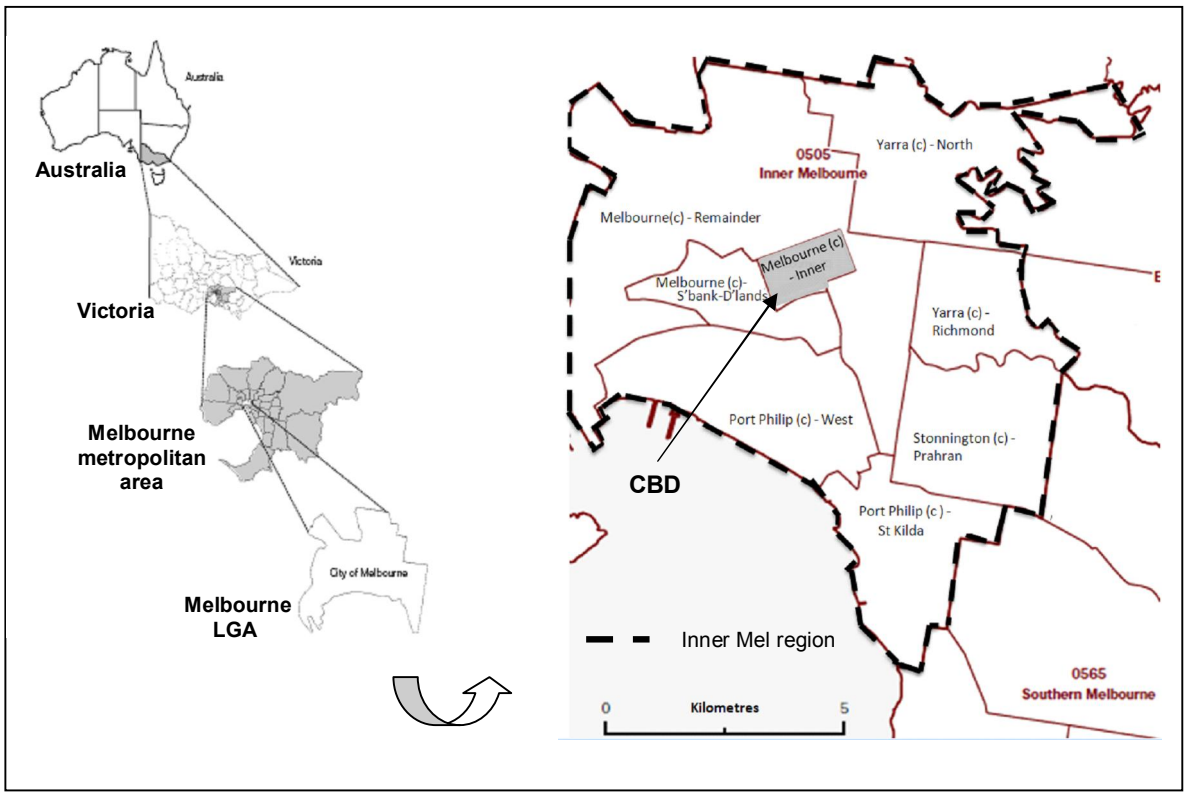
As mentioned in the research methodology, this research selects Melbourne Central Business District (CBD) as the case study to explore the economic impacts of agglomeration economies associated with urban passenger rail. This chapter introduces Melbourne CBD and its related travel issues. Focus is given to the AM peak period of a typical weekday since the employment suppression impact of rail congestion is envisaged to be most significant during this period of time. This employment suppression is hypothesised to be associated with a loss of potential agglomeration economies. The use of Melbourne CBD as a forum for the research is also justified in this chapter.

This chapter is organised in the following order.

- **Section 4.2 -** **Melbourne CBD and its Employment Profile** introduces Melbourne CBD with focus on its employment profile.
- **Section 4.3 -** **Travel Characteristics of CBD Employees** presents the travel behaviour of CBD employees and the car ownership level of those who uses the rail system to work.
- **Section 4.4 -** **Assessment: Congestion Status of Melbourne Train Network** examines the congestion level of Melbourne train network serving the CBD.
- **Section 4.5 -** **Justification to Adopt Melbourne CBD as a Case Study** justifies the use of Melbourne CBD as case study for this thesis.
- **Section 4.6 -** **Summary** concludes the chapter.

4.2 Melbourne CBD and its Employment Profile

Melbourne CBD is the centre city of Melbourne Local Government Area (LGA) located within Melbourne metropolitan area – see Figure 4.1. The Australian Bureau of Statistics (ABS) refers formally to Melbourne CBD as the Melbourne (C) Inner Statistical Local Area (SLA). According to the definition of ABS, Melbourne LGA[1] is a subset of Inner Melbourne region[2] (outlined in Figure 4.1) which also includes Port Philip and Yarra LGA as well as Stonnington (C) – Prahran SLA.



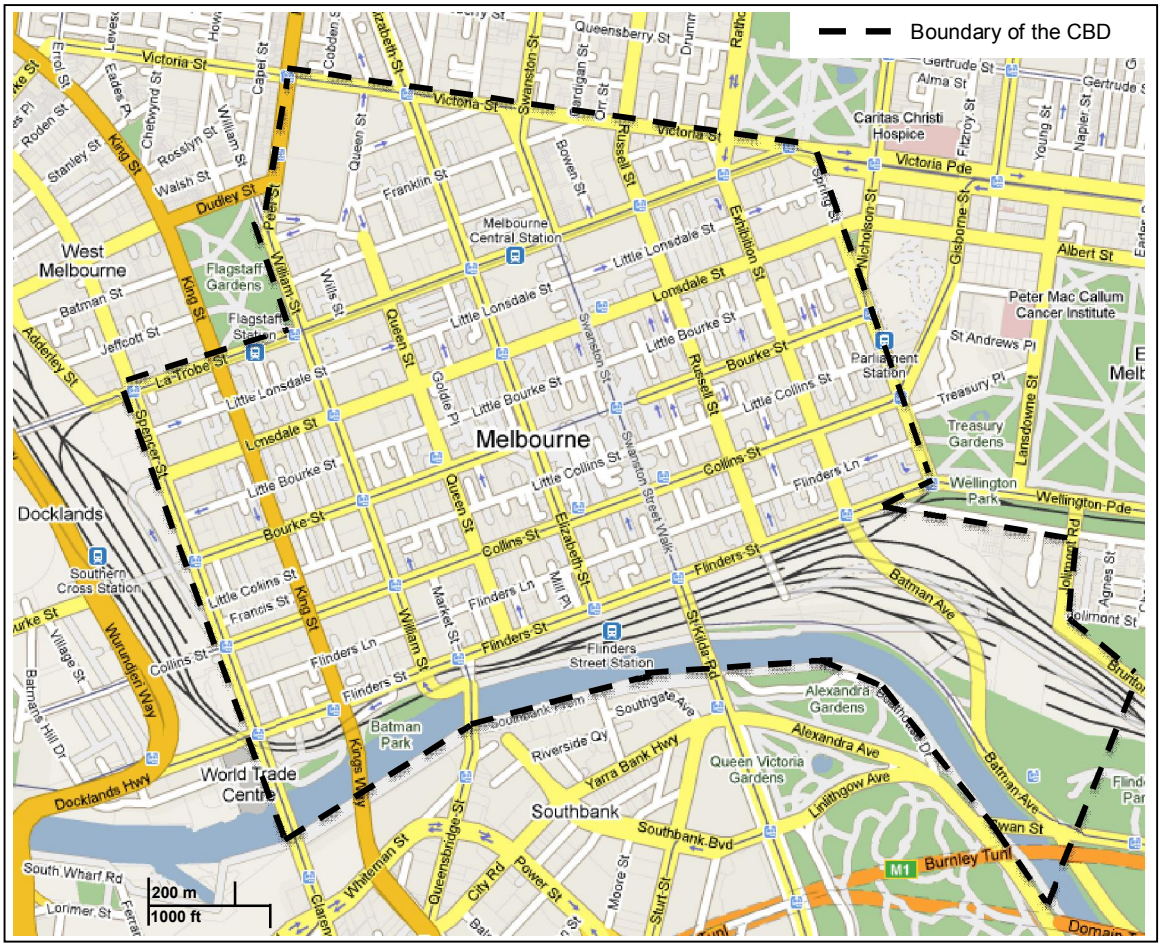
Source: Developed from Melbourne City Council (2003) and ABS (2009e)

Figure 4.1: Location of Melbourne CBD

[1] Melbourne LGA comprises of Melbourne (C) Inner, Melbourne (C) Southbank-Docklands and Melbourne (C) Remainder SLAs.

[2] Inner Melbourne region is defined here to facilitate the flow of the subsequent TERM modelling chapter (Chapter 8). The TERM modelling research has been conducted on the basis of Inner Melbourne region – see Chapter 8 for more details.

As defined by the City of Melbourne (2006), Melbourne CBD is largely bounded by Victoria Street to the north, Spencer Street to the west, the Yarra River (or Flinders Street) to the south and Spring Street to the east – see area outlined in Figure 4.2. The 3.54 km^2 CBD is approximately one-tenth the size of Melbourne LGA (land area of 36.5 km^2) (City of Melbourne, 2006).



Source: Developed from GoogleMaps Australia and City of Melbourne (2006)

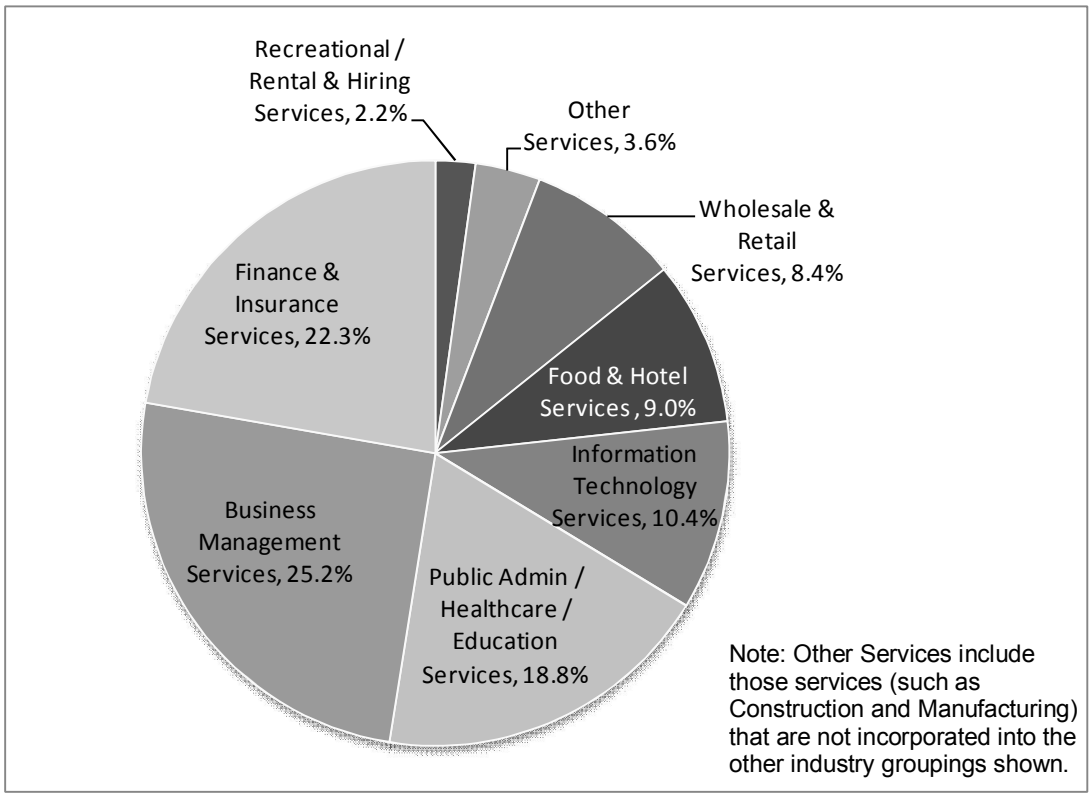
Figure 4.2: Boundary of Melbourne CBD[3]

[3] As shown in Figure 4.1 and 4.2, there is some differences in the CBD boundary as defined by the City of Melbourne and ABS. This thesis adopts the CBD boundary defined by the City of Melbourne (2006) because of the better CBD employment and firm data from the City of Melbourne (2006).

4.2.1 Melbourne CBD's Employment Profile

According to the Census of Land Use and Employment (CLUE) data, there are about 8,200 firms (2006) within Melbourne CBD employing 200,500 workers (City of Melbourne, 2006). Of the 200,500 CBD employees, 70% are full-time workers; 30% are part-time and contract workers (City of Melbourne, 2006). Comparatively, the residential population within Melbourne CBD is very much lower at 14,500 (ABS, 2006c). Hence, the majority of employees in the CBD commute from elsewhere.

CLUE data also shows that about 75% of the CBD's employment are working in four main industry groups namely the Business Management, the Finance and Insurance, Public Administration, Healthcare and Education as well as the Information Technology services[4] – see Figure 4.3 (City of Melbourne, 2006). This figure suggests that knowledge rich industries are a significant part of the CBD's economy.



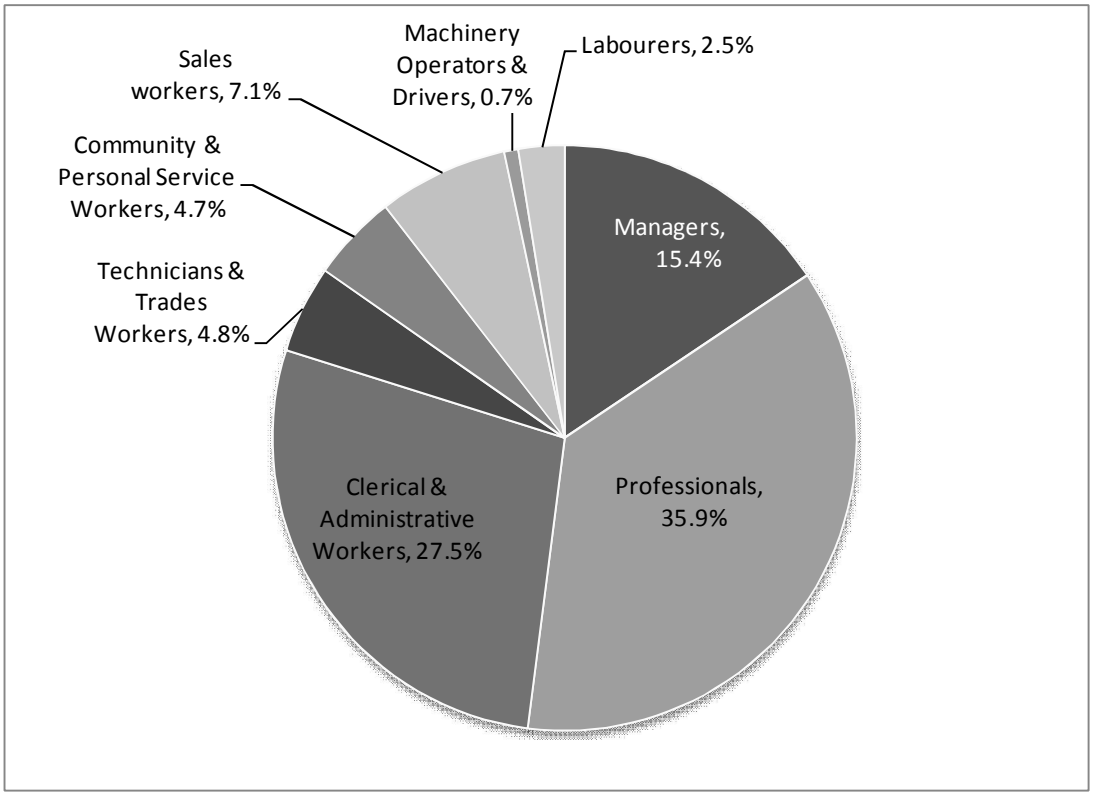
Source : City of Melbourne (2006)

Figure 4.3: Distribution of Employment across Industries within the CBD

[4] It is to be highlighted that while CLUE and ABS data classify industries into some 20 categories, the industrial classification has been simplified in this thesis to facilitate presentation and discussion. Also, the simplification of the industrial classification was also necessary to facilitate the Melbourne CBD employer survey which has been carried out in this research – see Chapter Six for more information.

Faulconbridge (2007) highlighted that bars and restaurants are an important feature of the knowledge economies of cities as they provide a venue for interaction which lead on to knowledge production. In the case of Melbourne CBD, the strong presence of the food and beverage industry[5] which accounts for about 6% of the overall CBD workforce is another indication of the existence of a knowledge-based economy.

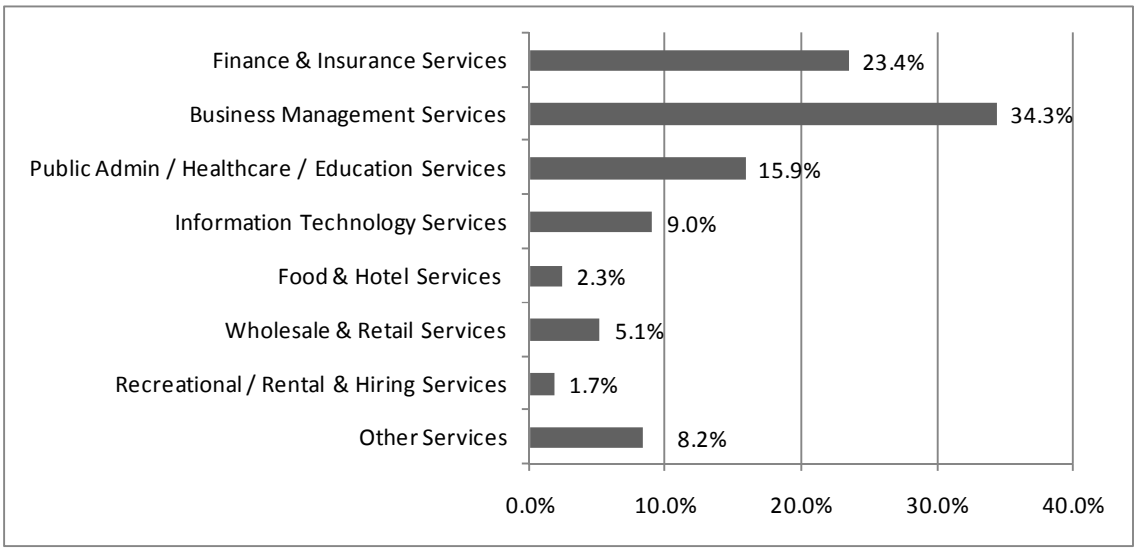
Figure 4.4 shows the composition of the CBD's employment by occupation type. As shown in Figure 4.4, Managers and Professionals make up about half (51%) of the total employment in the CBD. ABS (2006b) data indicates that the majority (about 82%) of the Managers and Professionals are working in the 4 sectors mentioned above – see Figure 4.5. This high percentage of highly qualified and trained workers is another indicator of the knowledge-based economy in Melbourne's CBD.



Source: ABS (2006b)

Figure 4.4: Composition of occupation type across employment within the CBD

[5] This is subsumed within the Food and Hotel Services sector in Figure 4.3. According to CLUE data, employment of the Food and Beverage sector make up about 6% of the total 9% of Food and Hotel Services shown in Figure 4.3.



Source: ABS (2006b)

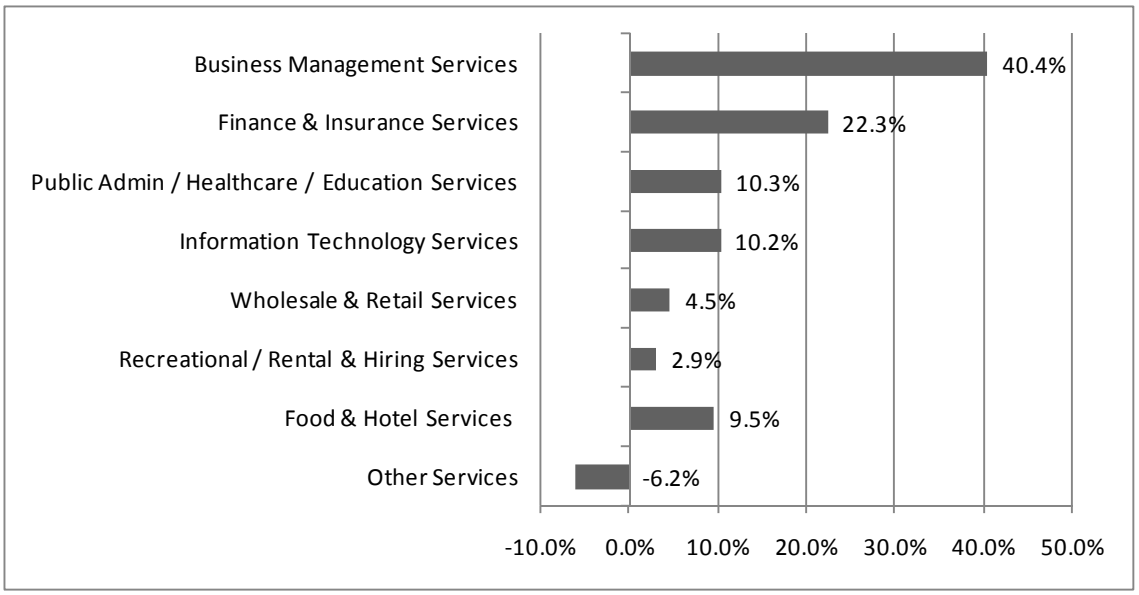
Figure 4.5: Distribution of Managers and Professionals across industries in the CBD

4.2.2 Melbourne CBD's Employment Growth

According to CLUE data, the total employment in Melbourne CBD has grown from 138,500 to 200,500 employees (or 45%) between 1992 and 2006 (City of Melbourne, 2006). According to SGS Economics and Planning Pty Ltd (2008), the total employment for Melbourne LGA (which includes the CBD) is forecast to grow by 4% in the short term and 16.5% in the long term[6]. Assuming that the CBD will also grow by the same proportion, it is estimated that the total employment for Melbourne CBD will hit 208,500 in the short term and 234,000 in the long term.

As shown in Figure 4.6, slightly more than 80% of the growth from 1992 to 2006 occurred within the Business Management, the Finance and Insurance, Public Administration, Healthcare and Education as well as the Information Technology services sectors – i.e. the four main industry groups which employ 75% of the total CBD employment. The significant employment growth in these 4 industry groups again substantiates the proposition of a knowledge-based economy in the Melbourne CBD.

[6] SGS Economics and Planning Pty Ltd (2008, page 3) indicated that the total employment in Melbourne LGA has grown by about 4% from 2006 to 2008. They forecast that the total employment in Melbourne LGA will grow by about 3.5% - 4% from 2008 to 2010 and from 2010 to 2012. Therefore, the short term growth rate for Melbourne LGA is taken to be 4%. The report also forecast the total employment in Melbourne LGA to grow by about 16.5% by 2016. This is taken to be the long term grow rate.

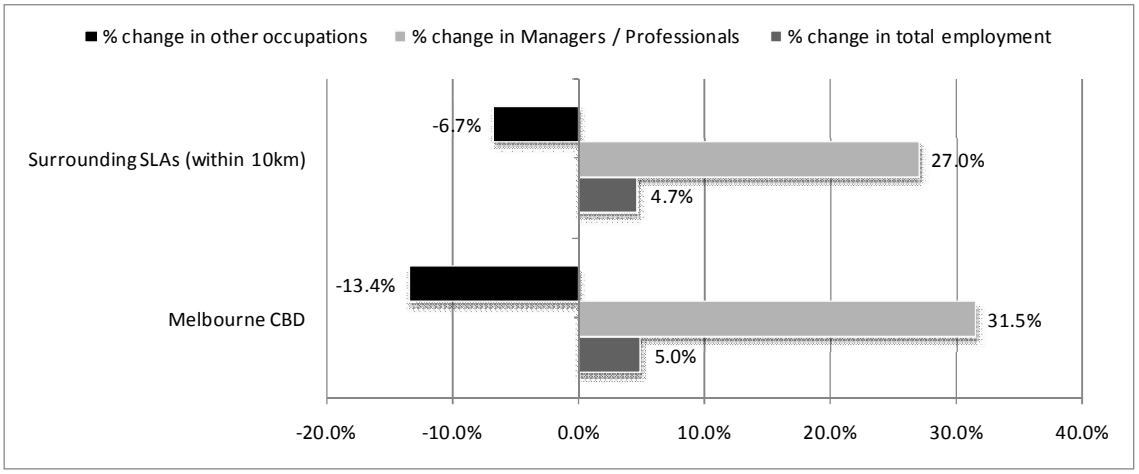


Source: City of Melbourne (2006)

Figure 4.6: Employment growth across industries in the CBD from 1992 - 2006

This analysis also examined employment growth figures of the surrounding Statistical Local Areas (SLA) within 10km from the CBD. The rationale to examine only the SLAs within 10km from the CBD arises from the work of Graham (2009), Addario and Patacchini (2006) and Rice et al. (2006) on the distance decay effects of agglomeration economies. Graham (2009) estimated that all localisation externalities are identified within a 10km radius from the firm. Addario and Patacchini (2006) estimated that agglomeration effects occur within local labour markets of up to 12km in radii on average while Rice et al. (2006) (as cited in Melo at al., 2009) found that increasing the size of the working population located beyond an hour's journey time will have almost no agglomeration impact on the local employment centre's productivity.

Figure 4.7 shows the 2001 to 2006 growth in the total employment of Melbourne CBD and the surrounding SLAs within 10km of the CBD. Melbourne CBD's total employment has grown by about 5% from 2001 to 2006; on the other hand, the total employment of the surrounding SLAs has also grown by about the same magnitude (4.7%) during this period of time. ABS data suggests that among the surrounding SLAs, Southbank and Docklands which is the area adjacent to the CBD, enjoyed the most significant employment growth of about 40% from 2001 to 2006.



Source: based on ABS (2006g, 2001b)

Figure 4.7: Employment growth of Melbourne CBD and surrounding SLAs from 1992 - 2006

Figure 4.7 suggests that the overall growth in total employment of the CBD and the surrounding SLAs (within 10km from the CBD) from 2001 to 2006 was primarily driven by the substantial increase in the total number of Managers and Professionals in these areas which outstripped the loss of jobs in other occupations.

ABS (2006g, 2001b) data shows that the total number of Managers and Professionals employed in the CBD has grown by about 31% between 2001 and 2006; during this time, the total number of Managers and Professionals working in surrounding SLAs was estimated to have increased by about 27%. While the percentage growth for the latter appears to be smaller, the total number of Managers and Professionals employed in the surrounding SLAs actually grew by about 45,500 in absolute numbers as compared to about 18,800 in the CBD from 2001 to 2006 (or about 2.5 times).

On the other hand, the total number of workers employed in other occupations for Melbourne CBD and surrounding SLAs have decreased by about 33,700 from 2001 to 2006 – about 11,600 jobs from Melbourne CBD and 22,100 jobs from the surrounding SLAs. The figures suggest that the total numbers of workers in other occupations in the surrounding SLAs were reducing at about twice the rate compared to the CBD from 2001 to 2006.

The above analysis suggests that in the last few years, Melbourne central area was actually growing at a much faster rate (than the 5 percent growth in CBD employment) via spreading to the surrounding SLAs especially the adjacent Southbank and Docklands area. The significant increase in the number of Managers and Professionals and the corresponding drop in the employment of other occupations in the surrounding SLAs suggest that the labour intensive sectors[7] in these SLAs have been progressively replaced by knowledge-based industries over the last few years.

It appears from the employment growth trend that it is possible that some of these knowledge-based firms may have spilled over or relocated over from the CBD into these surrounding areas. Feedback from some of the existing CBD employers obtained during the Melbourne CBD Employer survey (Chapter 6) suggest that one of the possible reasons for CBD employers to relocate out of the CBD could be to avoid rising congestion in the CBD.

4.3 Travel Characteristics of CBD Employees

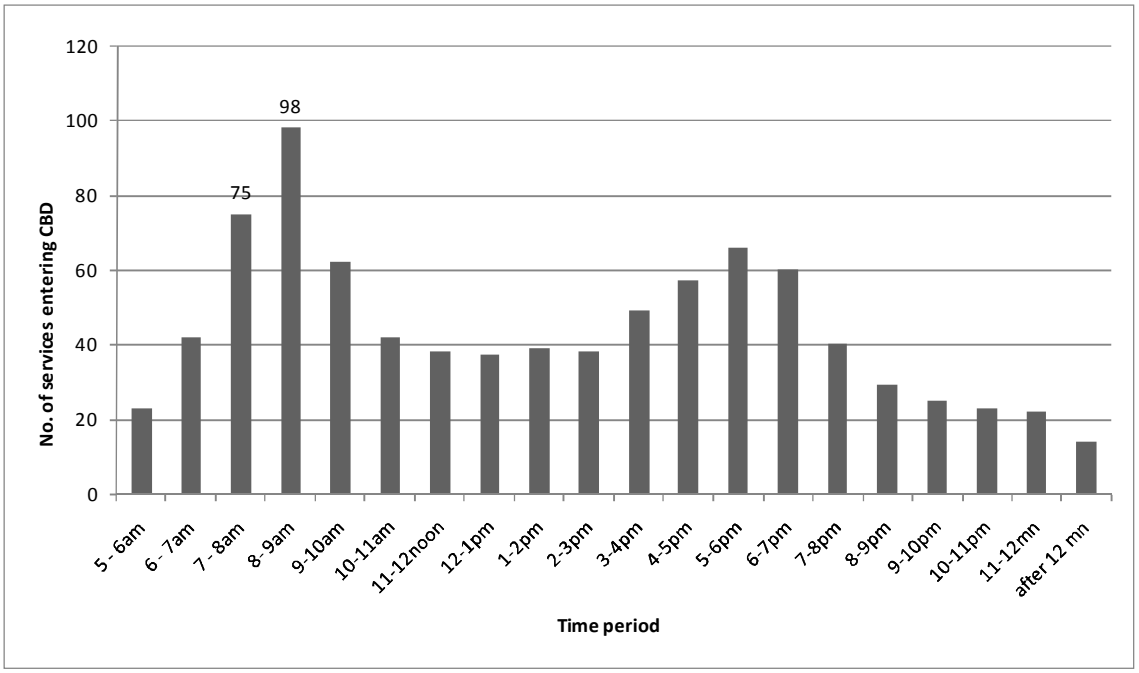
The following section presents the travel characteristics of CBD employees with a focus on those who use the urban rail system. The section begins with an overview of the transport network, in particular the rail network serving the CBD. This is followed by a secondary analysis of data from the Victorian Activity and Travel Survey (VATS) (Transport Research Centre (TRC), 1999) to understand the travel behaviour and car ownership level of CBD employees who use the urban rail system to access the CBD.

4.3.1 Overview of Transport Network serving Melbourne CBD

Melbourne CBD is today well served by public transport (PT) as well as a road network that is well connected to the highway system. The PT system serving the CBD comprises tram, buses and the urban passenger rail. The urban passenger rail serving the CBD is an integral part of the Melbourne passenger train network which serves the entire Melbourne metropolitan area. The network includes 15 rail lines that spans 370km in total route length with 211 stations across the entire metropolitan Melbourne (Connex Melbourne, 2008). Of the 211 stations, 5 serve Melbourne CBD – see Figure 4.2.

[7] ABS (2006f, 2001) data suggests that the Manufacturing, Construction and Retail services sectors were among the industries that saw the largest decrease in employment from 2001 to 2006 for the surrounding SLAs.

Figure 4.8 shows the profile of the total number of train services entering Melbourne CBD on a typical weekday. This profile is based on information from the train operating schedule shown in Metlink (2008)[8]. As shown in the figure, the train operation during a typical weekday is highest between 7 – 9 am where a total of 173 train services go into the CBD – 75 services are provided between 7 – 8 am and 98 train services are provided between 8 – 9am. Based on an average maximum carrying capacity of 798 passengers for a typical six-carriage train (as per the current franchise agreement, Department of Transport (DOT), 2008b), the train network is estimated to have the capacity to carry about 138,000 passengers into the CBD during 7 – 9 am from Monday to Friday.



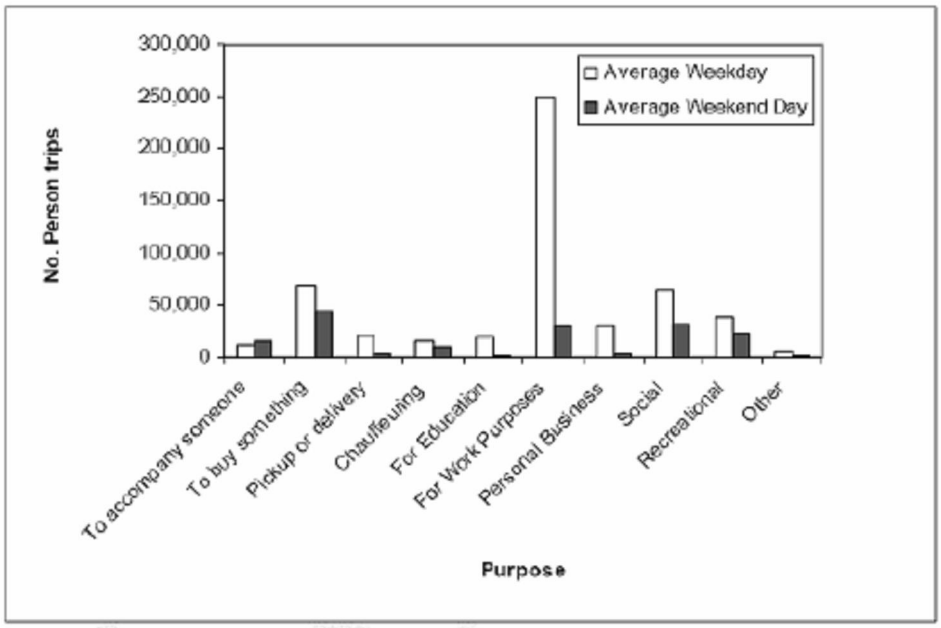
Source: Developed from Metlink (2008) – based on time table which started operation on 9th November 2008.

Figure 4.8: Profile of the total no. of train services entering the CBD on a weekday

[8] Metlink is a partnership of Melbourne's train, tram and bus operators as well as the Victorian State Government to provide commuters with a "one-stop-shop" information about services, fares and ticketing for the entire public transport network across Melbourne metropolitan area.

4.3.2 Travel Pattern of CBD Employees

VicRoads (2008a) suggests that each CBD employee makes one work trip on average into the CBD per weekday. Based on the total CBD employment figure of 200,500 given by CLUE (City of Melbourne, 2006), it is estimated that a total of 200,500 work trips are made into Melbourne CBD on an average weekday. According to VATS data (as cited in Currie et al., 2006), this 200,500 work trips account for about 48.8% of the total trips (all purposes) to the CBD on an average weekday – see Figure 4.9. This is not surprising since the CBD is the premier location within Victoria State for business and trade (Melbourne City Council, 2003).

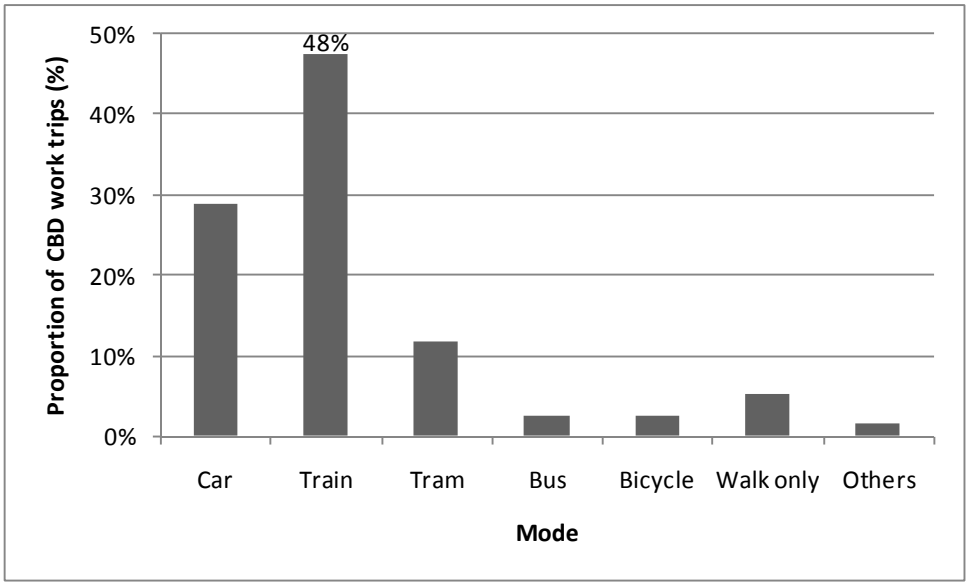


Note: Trips from outside the Melbourne Statistical Division are excluded. CBD incorporates the CBD plus the Queen Victoria Market.

Source: Victorian Activity and Travel Survey cited in Currie et al. (2006)

Figure 4.9: Purpose of trips into Melbourne CBD

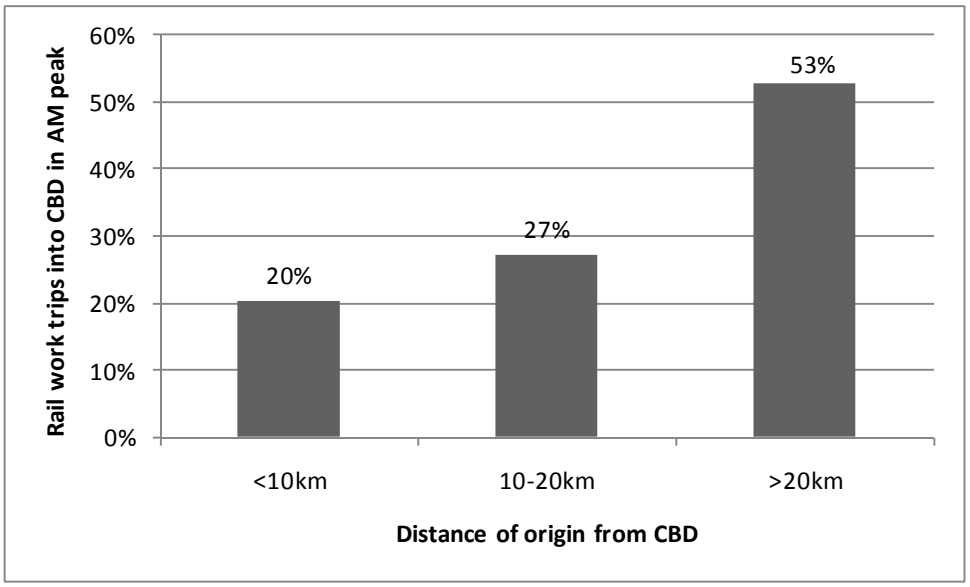
Information from ABS (2009c) suggested that about 48% (or 96,200 work trips) of daily CBD work trips are carried out on the urban passenger rail network – see Figure 4.10. According to VATS data (TRC, 1999), 75% of these work-related rail trips or 72,200 work trips are made during the 7-9am peak hour.



Source: ABS (2009c)

Figure 4.10: Mode Share of CBD work trips on weekdays

As shown in Figure 4.11, VATS data (TRC, 1999) also indicated that of the 72,200 work-related rail trips made in the AM peak, about 20% originate from areas within 10km from the CBD while about 27% are generated by employees who reside about 10-20km away from the CBD. The remaining 53% of employees who use rail to get to work in the morning stay more than 20km from the CBD.

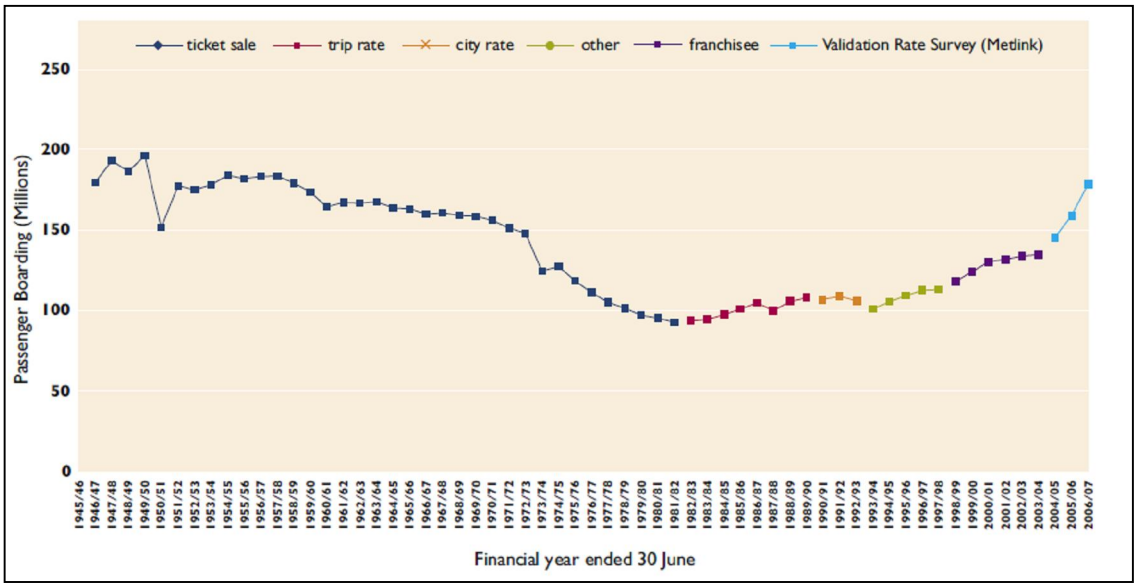


Source: Developed from VATS data (TRC, 1999)

Figure 4.11: Distribution of rail work trips into CBD in AM peak based on distance of origin from CBD

While work trips contribute a dominant share of the rail trips into the CBD in the AM peak, other trip purposes also contribute to the rising rail congestion serving the CBD. VATS data (TRC, 1999) suggests that work-related rail trips made up some 83% of the total amount of rail trips that go into the CBD in the morning peak of a weekday; the remaining 17% are for other purposes. Hence in total, about 87,000 trips (i.e. 72,200 / 83%) for all purposes are being made on the urban rail system into the CBD in the AM peak of a typical weekday.

The reliance of the CBD on the train system for its accessibility has been increasing significantly since Financial Year (FY) 2004-05 – see Figure 4.12. Information from DOT's FY2004–2009 annual reports indicates that annual train patronage has grown by a significant 53% between FY2004-05 to FY2008-09[9]. DOT attributed this train patronage surge largely as an outcome of the significant growth in the population and employment in Melbourne metropolitan area in the last decade or so.

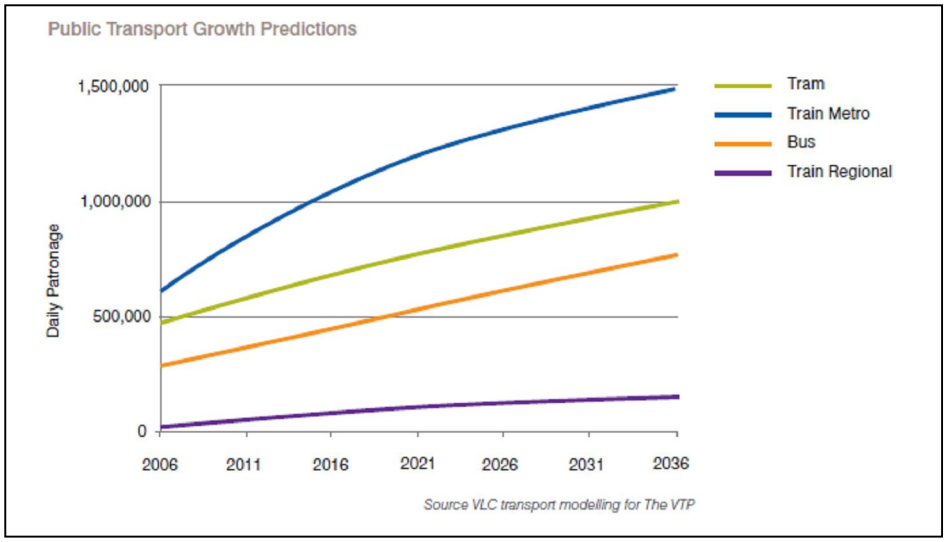


Source: DOT (2008e)

Figure 4.12: Melbourne Metropolitan Train Patronage (FY1945-46 to FY2006-07)

[9] Estimated using the annual train patronage figures from Department of Infrastructure (2005a), (2006), (2007) and DOT (2008a) and (2009a).

DOT (2009b) forecast that the rising trend for the metropolitan train patronage will continue – see Figure 4.13. This suggests that the train network in Melbourne will become increasingly more important to the accessibility of the CBD in the years to come. The high rail mode share of CBD work trips and the increasing importance of rail accessibility to the CBD suggest that any rail capacity constraint (i.e. rail demand exceeds rail capacity provision) is likely to have a growing detrimental impact on the accessibility and hence economy of the CBD.



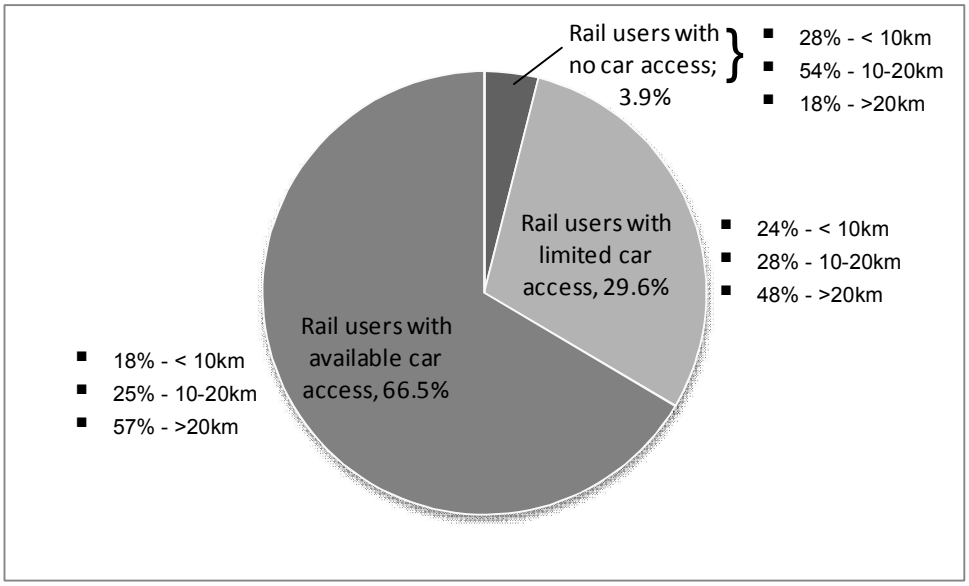
Source: DOT (2009b)

Figure 4.13: Growth predictions in the daily public transport patronage up to 2036

4.3.3 Car Ownership Level of CBD Employees who use Rail

It was established earlier that about 72,200 CBD employees use the urban rail system during the AM peak of a typical weekday. This section presents an assessment of VATS data to understand the car ownership pattern of this group of rail commuters. This understanding is relevant to this thesis as Transportation Research Board (2004) highlighted that private car availability has a significant influence on commuters' behaviour during times of rail capacity constraint.

As shown in Figure 4.14, about 4%[10] of total AM peak work trips into Melbourne CBD that are presently made on rail are carried out by those employees whose household does not own a car. Another 30% are made by those employees who have limited access to automobile use (i.e. there are more qualified drivers than the number of vehicles available in their households) while the remaining 66% are made by those employees who have ready access to car use (i.e. their households own more cars than the number of existing drivers).



Source: Developed from VATS data (TRC, 1999)

Figure 4.14: Car ownership level of CBD employees who takes the rail to work in AM peak hour

[10] This is a weighted average based on the sample size of the VATS data from 1994 to 1999.

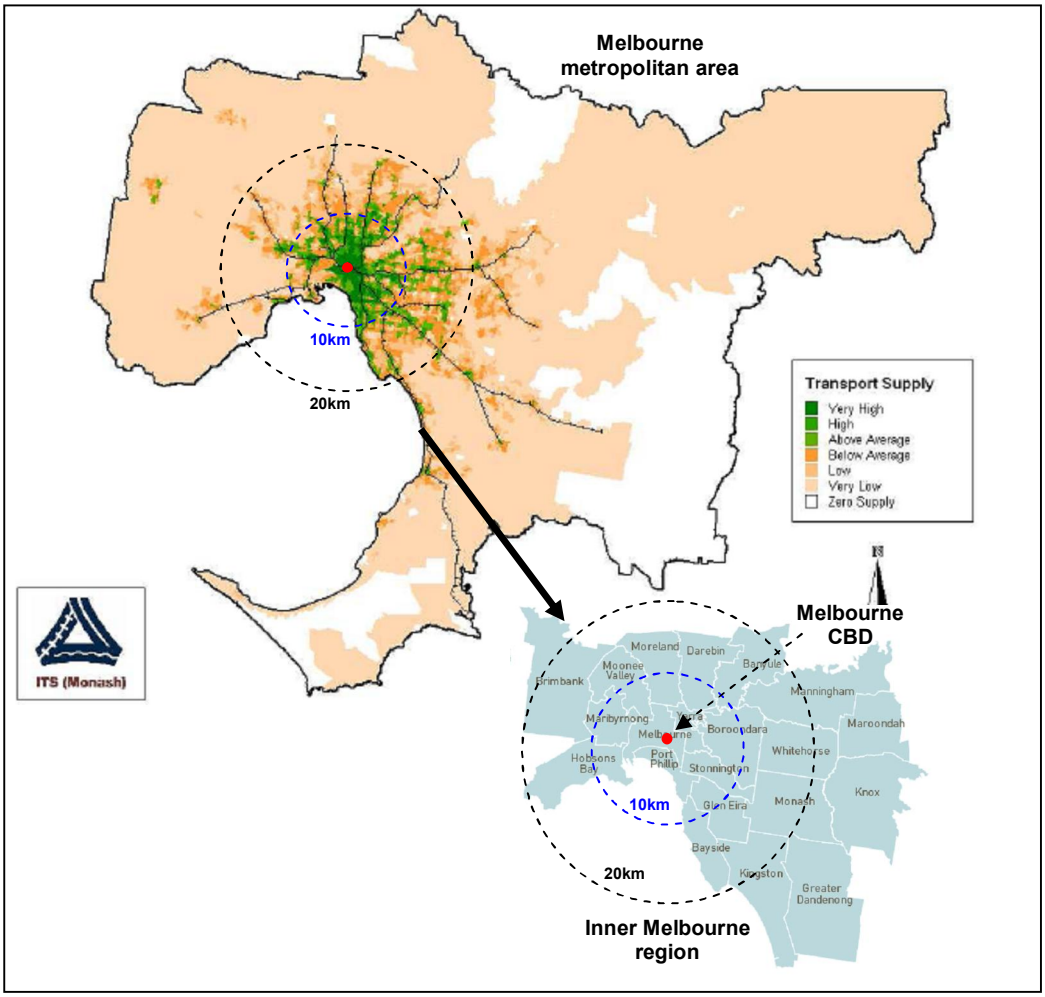
4.3.3.1 Employees with No Private Car Access

Figure 4.14 showed that of those CBD employees who had no private car access and uses the rail to work, about 82% reside within a 20km radius from the CBD. Of these, 54% resides within 10-20km from the CBD. This distribution is plausible as one would expect CBD employees with no car access to come largely from areas that are not too far from the CBD - work trips made predominantly on rail from areas within 20km from the CBD are estimated to be within the 30min to 1 hour threshold[11] which past studies (such as Bailey and Turok, 2001 and Batten, 1995) have suggested to be the journey time that most people are willing to travel for work purposes. In addition, Currie and Senbergs (2007) also found that many of the areas located within the 10-20km distance band (which is defined as Middle Melbourne in their work) have low supply of PT provision - see Figure 4.15. This low supply of PT provision also helps to explain the heavier reliance on the rail system of the employees with no car access in these areas.

As also shown in Figure 4.14, of the rail commuters with no car access, 28% reside within 10km from the CBD. This percentage is lower compared to those staying within the 10-20km distance band (54%). The lower reliance on rail for the former group is probably due to the availability of other attractive options such as the tram, cycling and walking.

According to VATS data (TRC, 1999), about 80% of the work-related tram trips to the CBD originated within areas that are 10km from the CBD. This is evidence that the tram is an attractive mode (which offers a competitive alternative to walking and cycling) for short work trips to the CBD.

[11] The journey to work travel times on rail were estimated using information from the Melbourne train timetables.



Source: Developed from Currie & Senbergs (2007) and Department of Sustainability & Environment (2005).

Figure 4.15: Level of public transport supply for the various Local Government Areas

Evidence that walking and cycling are viable options for employees residing within 10km from Melbourne CBD were found in the "Walking and Cycling: Census Analysis" (Bartley Consulting Pty Ltd, 2008). According to the census, some 49% of walking work trips and 35% of cycling work trips throughout the entire metropolitan Melbourne originated within areas that are 10km from the CBD. Of the walking work trips, the census analysis showed that the majority of these work trips started from areas that are within close proximity to the CBD or even within the CBD itself[12] (Bartley Consulting Pty Ltd, 2008). Cycling on the other hand, has a majority of the work trips commencing from areas that are slightly further away[13].

[12] These areas include largely Melbourne (C) – Inner, SouthBank–Docklands and Melbourne (C) Remainder SLAs.

[13] These areas include Yarra (C) – North, Moreland (C) – Brunswick, Darebin (C) – Northcote and Port Philip (C) – St Kilda SLAs.

On the destination end, the census showed that about 16% of the walking work trips and 18% of cycling work trips end within Melbourne CBD with majority of the remaining walking and cycling trips ending largely within areas surrounding the CBD such as the Southbank Docklands area (Bartley Consulting Pty Ltd, 2008). The evidence suggests that apart from the tram, walking and cycling are attractive options for employees who reside within 10km from Melbourne CBD.

Mackett (2001) suggested that walking is very popular for trips less than 1.6km while cycling is used mostly for trips less than 8km. This may explain the heavier reliance on the rail system of those employees who reside 10-20km from the CBD since cycling and walking are less attractive alternatives.

It is also observed that CBD employees with no car access and who reside 20km or further away from the CBD contribute about 18% of total rail patronage of this category. This essentially translates to less than 1% of the total work trips into the CBD that is made on rail (i.e. 18% multiplied by 4%). Apart from the longer journey time (which made working in the CBD less attractive), this lower figure is also possibly because the workers staying in these areas have even less mode connection options to access the nearest train station (since they do not own a car and the PT supply in the outer Melbourne region would be is low as suggested by Currie and Senbergs (2007)). Therefore, only those workers who are within walking or cycling distance to the train station would be able to take rail to work in the CBD.

4.3.3.2 Employees with Limited Private Car Access

As shown in Figure 4.14, some 30% of the rail commuters who presently work in the CBD come from households which have more licensed drivers than the number of vehicles available. The fact that this group of employees are currently using rail for their work trips suggests that they may have limited (or no) access to the car or the train mode is currently the most convenient mode choice.

Again it is observed that majority of this group of rail commuters with limited automobile access reside within 20 km from the CBD. However, this percentage is much lower as compared to those without car access (52% as compared to 82% of those without car access). This suggests that the car is an attractive and competitive option for this group of CBD employees as they have the option to take a lift from their family members or even drive occasionally to work. It is noted that the proportion of these employees who reside within the 10-20km distance band is still slightly higher than those who reside within 10km from the CBD. This again signals that the tram as well as walking and cycling are more attractive options for the latter.

It is also observed that the percentage of employees in this category who reside 20km or further away from the CBD is much higher at 48% as compared to 18% for those without car access. This significantly higher proportion may be due to the better accessibility to the train stations that these employees have - the availability of the automobiles albeit limited, means that these employees at least have a higher chance to catch a lift from their family members to the nearest train station. The higher percentage also suggests that if transfers to train stations are readily available, the rail mode is a very attractive option to CBD employees due to its faster and more predictable journey times.

4.3.3.3 Employees with Ready Private Car Access

As shown in Figure 4.14, about 66% of the rail commuter trips into the CBD in the AM peak are carried out by those employees who have ready access to a car i.e. there are the same or more automobiles available in the household than number of licensed drivers. It is observed that about 43% of the employees in this category reside within 20km from the CBD. This is lower compared to those employees with limited or no automobile access; it reinforces the earlier proposition that the automobile mode is an attractive and competitive mode choice even for those who reside within 20km from the CBD.

Again, VATS data indicate that the proportion of employees in this category who reside within the 10-20km distance band is slightly higher than those who stay within 10km from the CBD. This supports the earlier suggestion that walking, cycling and the tram are attractive options for the latter group of employees.

The percentage of employees in this category who reside 20km or further away from the CBD is again higher at 57% as compared to those with limited (48%) and no car (18%) access respectively. This higher percentage may be attributed to the easy accessibility to the train stations that these employees have - the ready availability of the automobiles means that these employees are always able to catch a ride from their family members to the nearest train station or even park-and-ride. The higher percentage supports the earlier suggestion that if transfers to train stations are readily available, the rail mode is the preferred mode choice of those that reside furthest away from the CBD.

4.3.3.4 Assessment

An assessment of VATS data suggests that about 96% of work-related rail trips into the CBD are carried out by employees who have access to automobile use; of these rail commuters, about 80% reside at least 10km from the CBD. This suggests that the train mode is currently the most attractive mode choice for CBD workers, in particular those that reside more than 10km from the CBD due to its faster and more predictable journey times.

In addition, the VATS data analysis also suggests that the availability of mode connection options to access the nearest train station would further enhance the attractiveness of the rail mode to employees who stay more than 10km from the CBD. The low supply of alternative PT modes in these areas has also contributed to their heavier reliance on the rail system. On the other hand, the VATS data analysis suggests that walking, cycling and the tram are attractive alternatives for CBD employees who stay within 10km from the CBD. This explains their lesser reliance on the rail system.

Overall, the assessment suggests that in an event of rail capacity constraint, the affected rail users are most likely to switch to the automobile mode because of the following reasons.

1. Accessibility to car use is high among the rail users – 96% have access to car use.
2. 80% of the rail users reside more than 10km from the CBD where the supply of tram and buses are low.
3. Walking and cycling are not viable alternatives for this 80% of rail users.

4.4 Congestion Status of Melbourne Train Network

This section presents the benchmarking of the current and future positions of the overall capacity of the train network serving Melbourne CBD in the AM peak i.e. to compare the total carrying capacity provided and utilised to serve the CBD in the AM peak. This benchmarking is necessary so that this research is able to interpret how the traffic congestion status derived using the Melbourne Integrated Transport model (MITM) (presented in Chapter Five) fits into the real world.

It is noted that with the limited information available, this benchmarking exercise was only able to provide an overview of the congestion problem pertaining to the overall rail network rather than specific rail lines. In addition, data constraints also meant that this exercise was only able to draw some broad conclusions about the rail congestion problem facing the CBD during the AM peak hour and not the peak-within-the peak.

Details of the benchmarking assessment are presented in Appendix A of this thesis. An outline of the methodology and the key findings are presented here in the following sequence.

- **Section 4.4.1-** **Methodology** outlines the method that was adopted for this benchmarking exercise.
- **Section 4.4.2 -** **Assessment - Rail Capacity Constraint Status** presents the AM peak congestion status of Melbourne train network facing Melbourne CBD from FY2004-05 to FY2014-15.

4.4.1 Methodology

The methodology adopted in this rail capacity benchmarking exercise is as follows:

Step 1: Estimation of AM peak rail capacity provision

The train fleet size available to serve Metropolitan Melbourne over the last few years was based on information from DOT's (including the former Department of Infrastructure) annual reports. The available fleet size from FY2010-11 to FY2014-15 was estimated using rolling stock procurement information from the Victorian Transport Plan (VTP) (DOT, 2009b).

Information from the ex-rail operator (Connex Melbourne, 2009)[14] suggests that the trains available for operation included 4 "standbys". Based on the train service time-tables (Metlink, 2008), it was estimated that about 20% of trains (excluding those on standbys) were put through the network twice during the 7-9 am peak period to serve the CBD[15]. Therefore, the total number of train services entering the CBD for each year was estimated as follows:

Total number of train services serving CBD in AM peak
= (total fleet size – 4 "stand-by" trains)*120% (Equation 4.1)

The total AM peak carrying capacity (seating plus standing capacity) provided to serve the CBD from FY2004-05 to FY2014-15 was estimated based on an average maximum carrying capacity of 798 passengers per train as indicated in the Metropolitan Train Franchise tender documents (DOT, 2008b) i.e.

Total rail capacity provided to serve the CBD in AM peak
= (total number of train services in AM peak)* 798 passengers

(Equation 4.2)

[14] Obtained via personal communication.

[15] Based on Metlink's (2008) train service timetables, all train services in the AM peak across the entire metropolitan network enters the CBD. This means that the total fleet size available to serve the Melbourne metropolitan area in the AM peak essentially serves Melbourne CBD.

Step 2: Estimation of AM peak hour rail demand

To estimate the AM peak rail demand for train services operated into the CBD from FY2004-05 to FY2009-10, the annual train patronage figures reported in DOT's annual reports were used. The daily rail ridership projections from the VTP (DOT, 2009b) were adopted to estimate the AM peak rail demand from FY2010-11 to FY2014-15

The annual train patronage volumes were then converted to average weekday patronage figures by applying an annualisation factor of 295 recommended by Connex Melbourne (2009). The 7-9am peak hour train ridership was then estimated based on the following daily rail patronage information from Connex Melbourne (2009).

- The 7-9am peak accounted for some 28% of the daily patronage for an average working weekday.
- The peak direction heading towards the CBD make up about 90%[16] of the AM peak rail demand.

Equation 4.3 shows how the AM peak rail demand is estimated from the above information.

AM peak rail demand in the direction of the CBD
= (Annual train patronage volume / 295) * 28% * 90% (Equation 4.3)

Step 3: Estimation of AM peak rail capacity constraint status

Rail capacity constraint (i.e. how much rail demand exceeds capacity provision) in the AM peak over time was estimated by comparing the rail demand against rail capacity provision as follows:

AM peak rail capacity constraint
= (AM peak rail demand – AM peak rail provision) / (AM peak rail provision)
(Equation 4.4)

[16] These include all rail trips that are going to the CBD as well as those that are travelling in the same direction but the CBD is not their destination.

4.4.2 Assessment - Rail Capacity Constraint Status

Figure 4.16 shows the estimated peak rail congestion from FY2004–05 to FY2014-15 estimated based on the methodology outlined in the preceding section. The black columns indicate the AM peak rail capacity provided and the grey columns indicate how much the AM peak rail demand exceeds provision. The percentages shown indicate how much rail demand exceeds capacity provision on average for each FY.

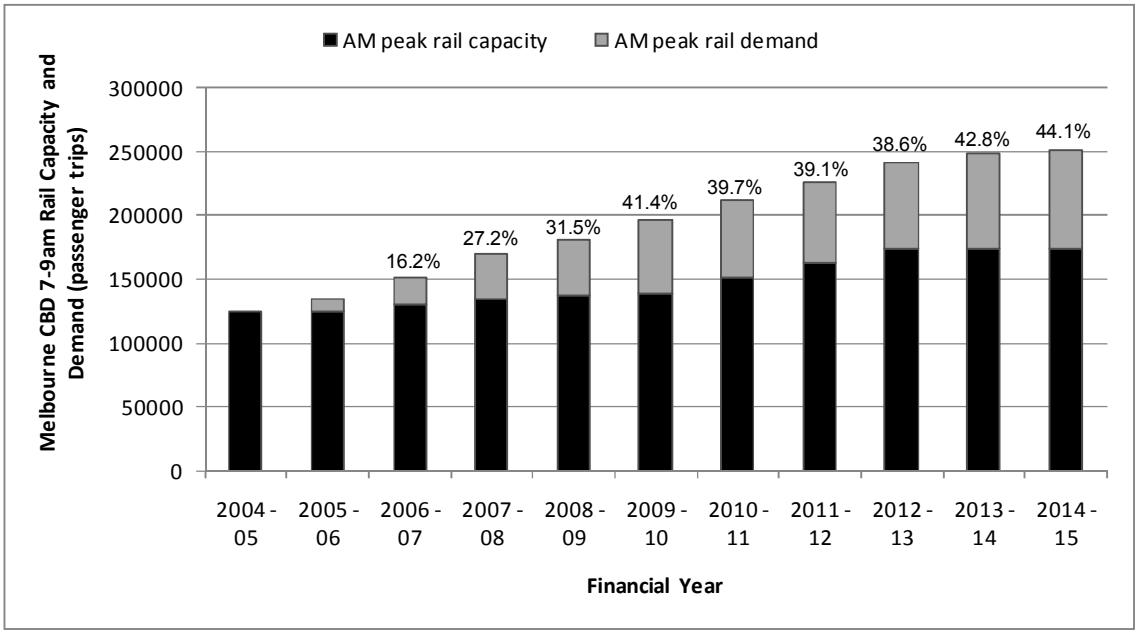


Figure 4.16: AM peak rail congestion level facing Melbourne CBD (FY2004-05 to FY2014-15)

As shown in Figure 4.16, in FY2004-05, AM peak rail capacity provided to serve the CBD was at the same level as the use. Thereafter rail capacity constraint grew steadily - from FY2004-05 to FY2008-09, the AM peak train patronage volume has grown by about 47% while the provision has increased by a fraction of this (12%).

At current status (2009), AM peak rail demand exceeds the provision by about 31.5%[17]. At this level of constraint, it is estimated that a typical train service heading towards the CBD during the AM peak would be carrying about 1,050 passengers on average.

[17] The rail benchmarking assessment was carried out in early 2009; hence the FY2008 – 2009 figure shown in Figure 4.16 was adopted in this assessment.

While 12 new trains are to be added by end of 2010, AM peak rail capacity constraint is envisaged to increase further to about 40% due to the 8% growth in AM peak rail demand as forecast by the VTP (DOT, 2009b). This will increase the average loading on a typical train service serving the CBD in the AM peak hour to about 1,120 passengers per train on average. However, with the subsequent delivery of the remaining 25 new trains over 2011 and 2012, the rail capacity constraint is envisaged to drop to about 38% in FY2012-13. A typical train service serving the CBD during the AM peak then is expected to carry about 1,100 passengers on average.

From FY2013-14 to FY2014-15, rail congestion level during the AM peak is envisaged to rise further since rail demand is expected to increase but no expansion in rail capacity provision is anticipated according to the VTP (DOT, 2009b). It is estimated that AM peak rail capacity constraint will grow by another 5% to about 44% in FY2014-15. When this happens, the average loading on a typical train service serving the CBD during the AM peak is estimated to be about 1,150 passengers per train.

Based on this evaluation, the rail capacity constraint facing Melbourne CBD in the next 5 years does not fluctuate very significantly but hovers around the 38 - 44% level. In terms of the average passenger loading per train service during the AM peak in the near future, train loadings ranges around 1,100 to 1,150 passengers per train on average; this is slightly higher than the current (2009) rail congestion status. This suggests that the Government's rail plan for the next 5 years, while not able to fully eradicate the rail congestion problem, is able to contain the congestion situation despite the 37% growth anticipated in rail demand for the next few years.

4.5 Justification to Adopt Melbourne CBD as a Case Study

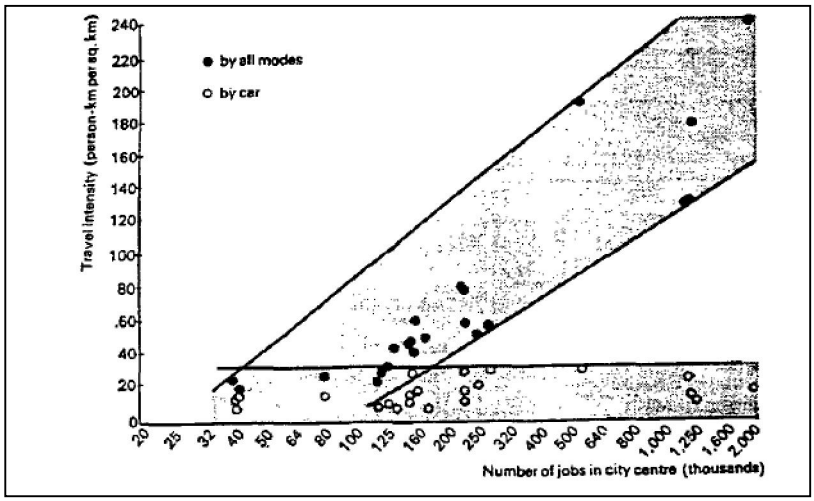
4.5.1 International Evidence

Various literature have highlighted that the importance of an effective urban passenger rail system to the success of cities (e.g. Hazel and Parry, 2004). Some even suggest that it is rail systems that drive city development (e.g. Wolmar, 2004, Fogel, 1964 and Fishlow, 1965).

Newman and Kenworthy (1989) examined the relationship between urban density and public transport use. Their comparative assessment amongst cities suggests that the higher the urban residential and employment density, the more reliant the city is on public transport, in particular urban rail, for the movement of its people. The importance of rail systems in supporting high urban densities of cities was succinctly summarised by Seskin and Cervero (1986) (as cited in Currie (2007, page 2.9)) which highlighted that "urban density is the primary determinant of transit ridership". This evidence can be used to suggest that rail investments are needed to support cities with high urban densities as "only rail transport can meet the transport needs of heavy demand corridors while maintaining high travel speeds and predictability of arrival and departure times" (Land Transport Authority, 1996 page 8).

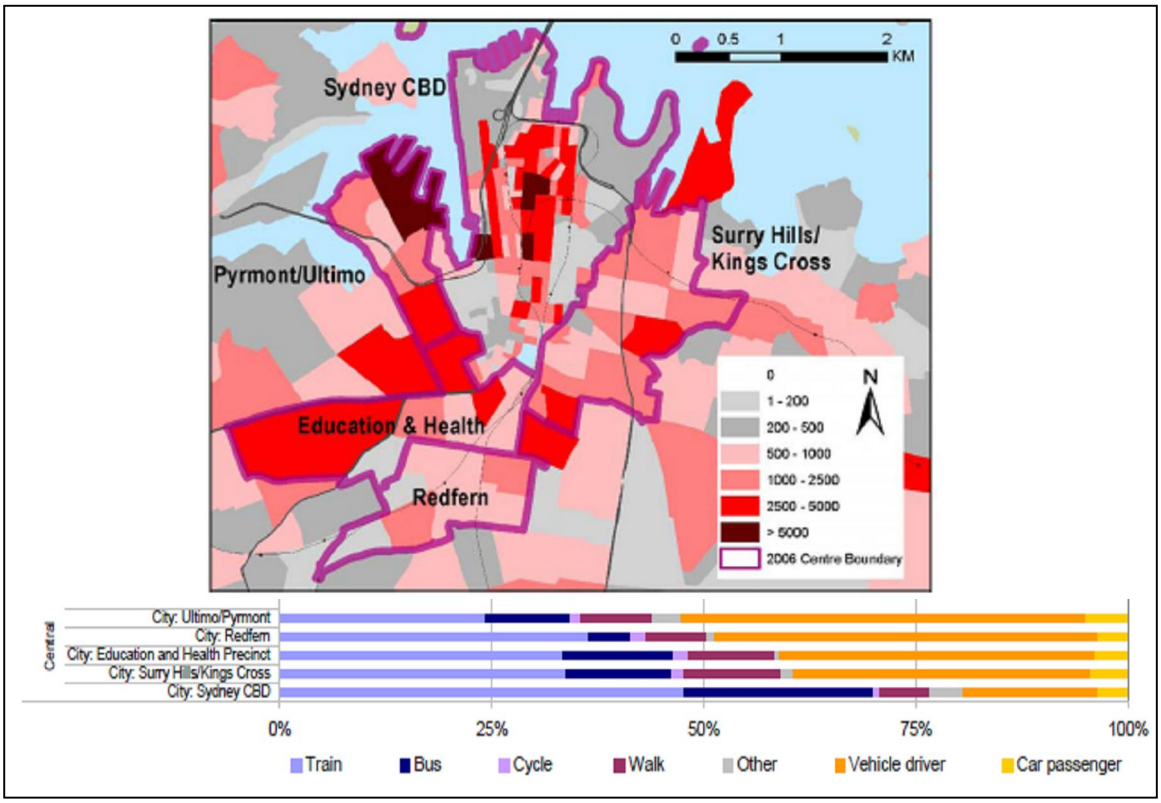
Within a city, there is also evidence to suggest that there is a strong relationship between transit usage and urban density. International evidence also indicates that the journey-to-work on PT increases sharply when the CBD attracts 150,000 or more jobs (Ellison, 1985) – see Figure 4.17. Ellison (1995) highlighted that rail transport in particular promotes higher urban densities (and vice versa).

Figure 4.18 shows the employment densities for Sydney CBD and the surrounding major employment centres in Sydney metropolitan area. As evident from the Transport Data Centre (TDC) (2008) data, Sydney CBD which has the highest concentration of employment in Metropolitan Sydney also has the highest rail mode share of journey-to-work (47.7%). This suggests that the urban rail system plays an important role in the accessibility of Sydney CBD for its workers.



Source: Ellison (1995)

Figure 4.17: Travel intensity of work journeys in city centres



Source: TDC (2008)

Figure 4.18: Employment densities and journey-to-work mode share for Sydney's key employment centres

In the case of Melbourne metropolitan area, information from VicRoads (2008a) shows that Melbourne CBD (which VicRoads (2008a) termed as Melbourne (C) Inner SLA) is the top destination in Metropolitan Melbourne in terms of the daily total number of journey-to-work trips made across the entire metropolitan area – see Table 4.1[18]. Of these daily journey-to-work trips made to Melbourne CBD, about 63% were carried out on PT (VicRoads, 2008a). As shown in Figure 4.10 earlier, rail has the highest mode share among the PT systems serving Melbourne CBD. This data supports the argument that rail transport is important in supporting areas with large employment agglomerations such as Melbourne CBD.

Table 4.1: Total Journey-to-work trips from Melbourne metropolitan area to Melbourne CBD and corresponding public transport share

Table 2. Journey to Work from Region (All Modes)

Journey to Work from Melbourne Statistical Division to:

Year: / *Destinations:*	1996 Number of Persons	2001 Number of Persons	2006 Number of Persons	1996-2001 Total % Growth	2001-2006 Total % Growth	1996-2001 Average % Growth/Yr	2001-2006 Average % Growth/Yr
Melbourne (C) - Inner	119,029	139,249	146,233	17.0	5.0	3.2	1.0
Melbourne (C) - Rest	119,500	124,155	136,226	3.9	9.7	0.8	1.9
Work destination not stated	46,502	69,609	86,202	49.7	23.8	8.4	4.4
Monash (C)	76,588	81,479	85,940	6.4	5.5	1.2	1.1
Gr. Dandenong (C)	61,071	65,377	72,288	7.1	10.6	1.4	2.0
Victoria - No fixed workplace address	37,814	60,877	70,029	61.0	15.0	10.0	2.8
Kingston (C)	63,134	65,587	65,968	3.9	0.6	0.8	0.1
Port Phillip (C)	55,036	61,462	63,634	11.7	3.5	2.2	0.7
Hume (C)	45,709	52,276	58,765	14.4	12.4	2.7	2.4
Whitehorse (C)	49,001	56,180	58,615	14.7	4.3	2.8	0.9
Boroondara (C)	52,905	53,966	57,524	2.0	6.6	0.4	1.3
Yarra (C)	52,477	53,402	55,725	1.8	4.4	0.4	0.9
Knox (C)	49,133	52,542	55,554	6.9	5.7	1.4	1.1
Stonnington (C)	39,429	41,533	43,192	5.3	4.0	1.0	0.8
Brimbank (C)	30,103	35,717	42,668	18.6	19.5	3.5	3.6
Casey (C)	23,892	31,929	41,347	33.6	29.5	6.0	5.3
Darebin (C)	43,221	37,917	38,823	-12.3	2.4	-2.6	0.5
Mornington P'sula (S)	27,638	33,490	37,178	21.2	11.0	3.9	2.1
Maroondah (C)	32,289	34,177	36,207	5.8	5.9	1.1	1.2
Yarra Ranges (S)	26,808	32,204	34,382	20.1	6.8	3.7	1.3
Others	341,071	361,302	391,378	5.9	8.3	1.2	1.6
Total	1,392,350	1,544,430	1,677,878	10.9	8.6	2.1	1.7

Table 6. Journey to Work from Region (By Public Transport)

Journey to Work from Melbourne Statistical Division to:

Year: / *Destinations:*	1996 Number of Persons	2001 Number of Persons	2006 Number of Persons	1996 % Public Transport	2001 % Public Transport	2006 % Public Transport
Melbourne (C) - Inner	60,336	75,349	83,497	56.2	61.0	63.0
Melbourne (C) - Rest	26,536	30,542	38,249	24.9	28.4	32.0
Port Phillip (C)	6,974	8,213	11,660	14.3	15.5	20.8
Yarra (C)	6,917	6,715	8,806	14.9	14.7	18.3
Work destination not stated	3,089	5,644	8,376	12.4	11.7	13.1
Stonnington (C)	3,942	4,391	5,030	12.1	13.0	14.4
Boroondara (C)	3,635	3,707	4,710	8.3	8.5	10.0
Monash (C)	2,879	2,904	3,533	4.3	4.1	4.7
Whitehorse (C)	2,441	2,615	3,290	6.0	5.6	6.7
Kingston (C)	2,358	2,392	2,475	4.2	4.2	4.3
Victoria - No fixed workplace address	1,002	1,722	2,243	3.0	3.2	3.7
Darebin (C)	2,498	1,976	2,154	6.6	6.1	6.5
Gr. Dandenong (C)	1,898	1,798	1,971	3.5	3.1	3.0
Maribyrnong (C)	1,734	1,611	1,804	6.8	6.5	7.5
Glen Eira (C)	1,549	1,570	1,750	6.8	6.9	7.7
Moreland (C)	2,142	1,673	1,740	7.5	6.5	7.0
Moonee Valley (C)	1,569	1,523	1,703	7.0	6.5	7.1
Knox (C)	1,331	1,211	1,348	3.2	2.7	2.9
Banyule (C)	1,237	1,124	1,339	4.9	4.3	4.8
Melbourne Undefined	639	962	1,257	13.1	34.7	35.0
Others	11,463	10,872	12,951	3.7	3.1	3.3
Total	146,169	168,514	199,886	12.4	13.1	14.1

Source: VicRoads (2008a)

[18] Table 4.1 shows that 146,233 work trips are made into Melbourne CBD per day. This is noted to be lower than the 200,500 daily work trips as estimated in Section 4.3.2. The discrepancy is due to the difference in Melbourne CBD boundary defined by ABS (which VicRoads (2008a) is based on) and CLUE (which is adopted in this thesis – see footnote 3.

A statistical assessment to establish the relationship between total CBD employment and daily rail capacity provision was carried using data of twenty international cities from the International Association of Public Transport's (2001) Millennium Cities database – see Chapter Seven for the list of the selected cities and details of the analysis. The statistical analysis revealed that the total employment of a CBD is highly correlated with its rail capacity provision – with a Pearson correlation coefficient of .85 at significance level of .01 (2-tailed). A Univariate Analysis of Variance yielded an adjusted R^2 value of .711 which suggests that daily rail provision accounts for about 71% in the variability of the CBD's total employment. Regression analysis further suggests that a 1% increase in daily rail provision is associated with a 0.542% increase in total CBD employment which is significant.

All this evidence suggests that Melbourne CBD is a good candidate for examining the agglomeration economies associated with urban rail as its accessibility is heavily dependent on the rail system and its economy has also enjoyed strong economic growth over the past decade and continues to perform above expectations with increasing employment (Service Skills Victoria, 2007, Standard and Poor's , 2003).

In addition, the availability of data pertaining to employment and the travel patterns of Melbourne CBD (e.g. the CLUE and ABS) and the availability and readiness of MITM and the ORANI economic models further reinforces the choice of Melbourne CBD as the case study for this thesis.

4.5.2 Comparative Assessment of Five Major Australian CBDs

To further assess how reasonable Melbourne CBD is as a case study for this research, its employment and rail capacity provision was benchmarked against that serving the CBD of four other major Australian cities - Sydney, Brisbane, Perth and Adelaide. The approach to estimate the AM peak rail capacity provision and use is similar to that outlined in Section 4.4.1. An outline of the methodology and the key findings are presented next. Details of the comparative assessment are presented in Appendix B of this thesis.

4.5.2.1 Methodology

The approach adopted comprises the following 3 steps.

Step 1: Estimation of AM peak rail capacity provision

The overall rail capacity serving each CBD during 7 - 9 am was estimated based on information from the train service time-tables and the total carrying capacity (seating plus standing capacity) from the respective rail operators.

Step 2: Estimation of AM peak rail demand

The total amount of rail demand was estimated based on the total employment of each CBD and their respective rail mode share using Equation 4.5.

$$\text{Total CBD rail trips (7-9am)} = \left(\text{Total CBD Employment} * \text{Daily rail mode share} * \text{Proportion of CBD work trips made in AM peak}\right) / \text{Proportion of total AM peak rail trips into CBD that is for work purposes}$$

(Equation 4.5)

As explained in Section 4.3.2, VATS data analysis suggests that 75% of the work trips into Melbourne CBD are made during the 7-9am peak hour and that work-related rail trips made up some 83% of the total amount of rail trips that go into the CBD in the morning peak (TRC, 1999). In the absence of information, these factors are assumed for the other CBDs except Sydney.

For the case of Sydney, information from Transport Data Centre (TDC) (2009a) suggest that about 66% of the work-related rail trips going into Sydney CBD are made during 7-9am on a typical weekday. In addition, TDC (2009a) also indicated that work-related rail trips made up some 88% of the total amount of rail trips that go into the CBD in the AM peak of a weekday. These values were applied to Equation B1 to estimate the overall rail demand for Sydney CBD in the AM peak.

The employment figure for each CBD was obtained from the respective city council of the Local Government while the rail mode share was estimated based on information from customised ABS reports[19].

[19] For Perth CBD, there was no customised ABS report; hence the rail mode share was estimated from ABS (2006d, 2006k). For Sydney CBD, the rail mode share was estimated based on information from TDC (2008, 2009a, 2009b).

Step 3: Comparative Assessment of the Australian CBDs

Assess the findings of step (1) and (2) to ascertain how Melbourne CBD compares against the other Australian CBDs.

4.5.2.2 Results

Table 4.2 summarises the key findings of the comparative assessment. It shows the employment figures, AM peak rail capacity provision and use for each Australian CBD. The average AM peak loading factor shown is the ratio of the total rail demand against the total rail capacity provided to serve the CBD. This factor gives an indication of the average occupancy of each train service entering the CBD in the AM peak.

Table 4.2: Comparative Assessment of 5 Major Australian CBDs (2006)

CBD	Melbourne	Sydney	Brisbane	Perth	Adelaide
Total CBD employment (2006 figure)	200,500	230,000	104,750	61,800	66,700
CBD area (km^2)	3.5	4.2	2.5	7.5	3.8
CBD employment concentration (employees / km^2)	56,600	55,400	41,900	8,240	17,500
Daily rail mode share for CBD work trips	48%	47%	28%	22%	9%
Estimated AM peak rail demand for CBD[20]	87,000	82,800	26,600	12,300	5,400
Estimated AM peak rail capacity provision serving CBD	138,000	206,200	67,500	37,400	12,800
Average AM peak rail loading factor	**0.63**	**0.40**	**0.39**	**0.33**	**0.42**

Source: Developed from information from Metlink (2008), Department of Transport (2008b), CityRail (2009a, 2009b, 2009c), Brisbane CityTrain (2009a, 2009b, 2009c), TransPerth (2009a, 2009b), TransAdelaide (2009a, 2009b), ABS (2006d, 2006k, 2009a, 2009b, 2009c), TDC (2008, 2009a, 2009b), Brisbane City Council (2006), City of Melbourne (2006), Melbourne City Council (2003), City of Perth (2009), Adelaide City Council (2009) and Transport Research Centre (1999).

[20] This figure includes those AM peak rail trips into the CBD for non-work related purposes. As mentioned in Section 4.3.2, 72,200 work-related rail trips are made into Melbourne CBD in the AM peak; this is about 83% of the total amount of rail trips into the CBD in the AM peak. This 83% factor was used for the other CBDs except Sydney where corresponding information from TDC (2009a) were used. See Appendix B for more details of computation. It is also to be noted that the estimated AM peak rail demand for Melbourne CBD shown here cannot be compared against the rail demand shown in Figure 4.16. The latter includes all rail trips that are travelling in the direction towards Melbourne CBD but the CBD is not the destination (see footnote 16); the 87,000 trips shown in Table 4.2 refer strictly to those rail trips whose destination is Melbourne CBD.

The results suggest that the train network serving Sydney and Melbourne CBDs have the highest provision and use. It appears from Table 4.2 that a typical train service entering the various CBD between 7-9am is on average (weighted) about 50%[21] occupied – the Perth trains are least occupied with an average loading factor of 0.33 while the Melbourne trains are most well-utilised with an average 0.63 loading factor. It is not surprising that the Melbourne trains are most well-utilised comparatively since Melbourne CBD has the highest employment concentration among the CBDs while its rail capacity provision is about 50% lower than that serving Sydney CBD (which has the second highest loading factor) albeit both CBDs having a similar rail mode share.

The comparative assessment suggests that Melbourne CBD has the highest employment concentration among the five CBDs and its trains have the highest utilisation. This supports the earlier proposition that Melbourne CBD is a good candidate among the five major Australian CBDs for examining agglomeration benefits associated with urban rail as any rail congestion impact on the CBD's productivity is likely to be most evident from Melbourne CBD.

4.6 Summary

This chapter introduces Melbourne CBD and presents its related travel issues. Focus is given to the AM peak period of a typical weekday since any employment suppression impact associated with rail congestion is envisaged to be most significant during this period of time.

The 3.54 km^2 Melbourne CBD is the centre city of Melbourne LGA. According to CLUE data, there are about 200,500 employees working in Melbourne CBD. Of these, 75% are employed in four main industry groups namely the Business Management, the Finance and Insurance, Public Administration, Healthcare and Education as well as the Information Technology services (City of Melbourne, 2006). While ABS data indicates that the CBD employment grew by about 5% over the last few years, the employment growth trend of the surrounding areas suggests that the CBD was actually growing at a much faster rate during this period of time via spreading of employment to surrounding areas especially the adjacent Southbank / Docklands area.

[21] This is a weighted average of the AM peak loading factor based on the total AM peak rail carrying capacity provision of the 5 CBDs; the weighted average AM peak loading factor based on total AM peak rail demand is about 0.52 which is not significantly different.

Melbourne CBD is presently well served by both highway and PT which include 5 train stations. Information from ABS (2009c) suggests that rail transport is an important mode for CBD employees, carrying 48% of the daily CBD work trips. Of these, 75% are made in the 7-9am peak period (TRC, 1999). Analysis of VATS data (TRC, 1999) suggests that about 4% of AM peak rail commuters into Melbourne CBD come from households that do not own a car. Another 30% are made by those employees who have limited access to automobile use while the remaining 66% are made by those employees who have ready access to a car. The analysis results suggest that in an event of rail capacity constraint, the affected rail users are most likely to switch to automobile use since most of them have ready access to car use and the poor supply of alternative PT modes.

According to Metlink (2008) and DOT (2008b), a total rail capacity to carry about 138,000 passengers is provided to serve Melbourne CBD during 7 – 9 am from Monday to Friday. Analysis suggests that the train system is today (2009) about 31.5% over capacity during the AM peak. This is expected to increase to 38% - 44% in the next few years given the anticipated growth in rail demand.

International and Australian evidence suggest that Melbourne CBD is a good candidate for examining the agglomeration economies associated with urban passenger rail. This is because of its high employment density and heavy reliance on the urban rail. In addition, the availability of data pertaining to employment and travel pattern of Melbourne CBD and the availability and readiness of MITM and the ORANI economic model further reinforces the choice of Melbourne CBD as the case study for this thesis.

CHAPTER 5

MITM Modelling

5.1 Introduction

The analysis of the Victorian Activity and Travel Survey (VATS) data carried out in Chapter Four (Section 4.3.3.4) suggests that in an event of a rail capacity constraint[1], the majority of the affected rail users are likely to mode switch to car use. The Melbourne Multi-modal Integrated Transport Model (MITM), which is an operational transport model of the Department of Transport (DOT), Victoria, has been used in this research to simulate the possible increase in road traffic arising from a rail capacity constraint serving Melbourne Central Business District (CBD).

The aim of this chapter is to introduce MITM and report the transport modelling approach and results. In addition, the potential employment suppression impacts estimated based on MITM's outputs and trip elasticities are also presented in this chapter – this is one of the 3 approaches used in this research to estimate the potential employment suppression impacts[2] associated with an urban rail constraint. Figure 5.1 shows how this transport modelling element (shown boxed in red) fits into the overall research methodology.

The decision to use MITM for this research was based on three considerations. Firstly, DOT is willing to share their documentation and expertise about this model. This is important to help mitigate the learning risk of MITM. Secondly, DOT's extensive use of MITM for its work demonstrates reliability and rigour of the model. More crucially, MITM is properly calibrated and ready for immediate use. This minimises any potential delay to the schedule of this candidature.

---

[1] This research defines a rail capacity constraint as a situation where the rail demand exceeds rail capacity provision.

[2] As mentioned in the research methodology (Chapter 3), this research measures the agglomeration effects in urban rail using 2 measures. The potential employment suppression impact is one of the measures. The other measure is the change in the accessibility of the CBD.

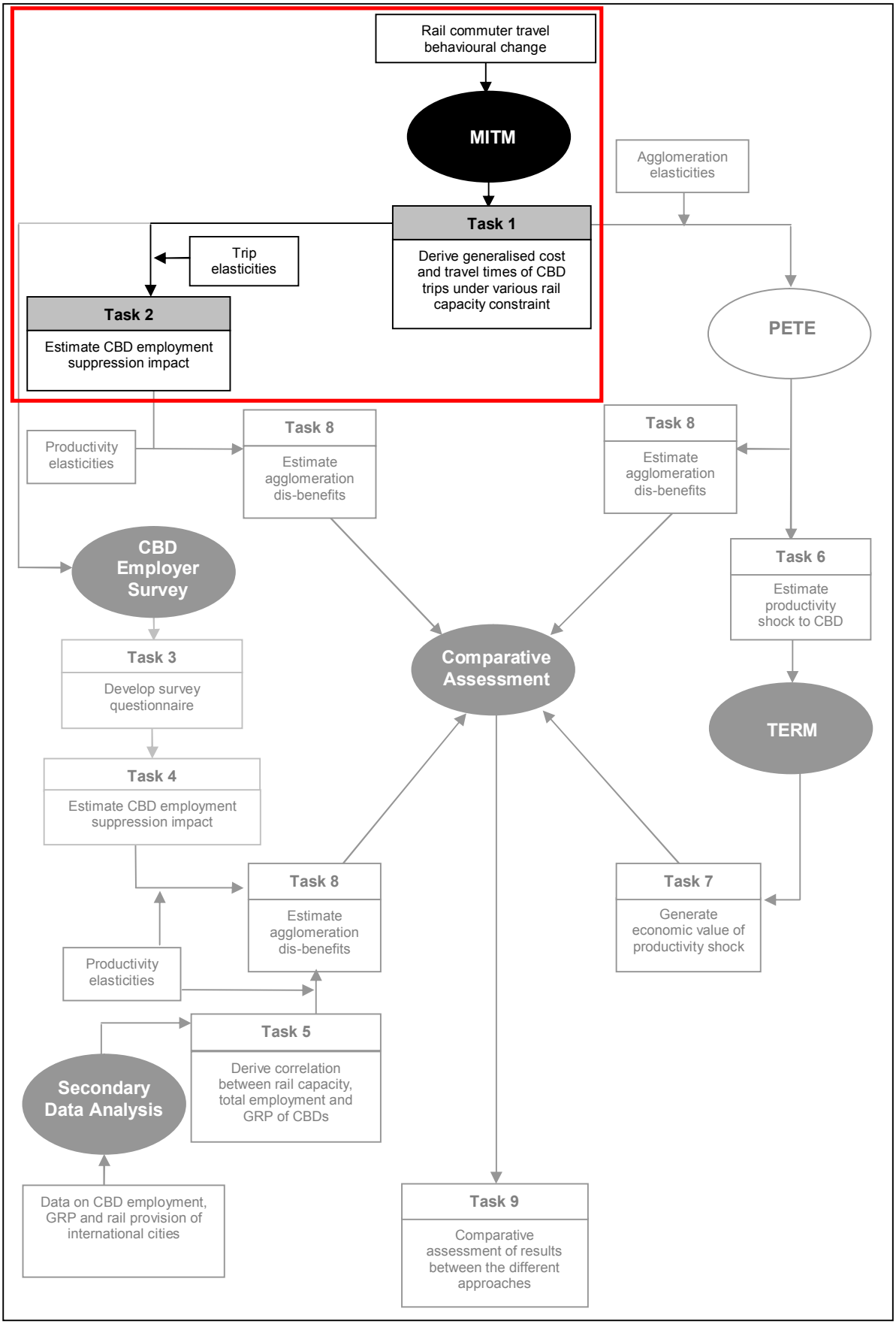


Figure 5.1: Research focus of Chapter Five

Figure 5.2 presents an overview of the MITM modelling framework carried out in this research. As MITM contains no modelling of capacity constraints, secondary research was first conducted to investigate how CBD employees are likely to change their travel behaviour in circumstances of a rail capacity constraint (i.e. rail demand exceeds rail capacity provision). The findings (which are reported in Section 5.3) are used to make appropriate assumptions in the application of the MITM model.

The increase in highway traffic has been modelled in MITM by first manipulating the AM peak highway demand matrix where the diverted rail-to-car trips are added to the base case highway matrix. A highway assignment with the new highway demand matrix is then carried out in MITM to simulate the increase in road congestion. Details of the modelling approach are reported in Section 5.4.

As shown in Figure 5.2, the output from MITM has been used to estimate how the AM peak travel times and generalised costs of highway trips into the CBD may change due to the rising rail and road congestion (Section 5.5). There are 3 purposes for these estimates.

1. To estimate the potential trip and labour supply suppression impacts associated with urban rail capacity constraint. The labour supply suppression impact has been estimated using changes in the generalised cost of travel from MITM and trip elasticity values from secondary research – these are reported in Section 5.6.
2. To act as an input to the CBD employer survey (Chapter 6). In particular, to specify road congestion impacts of rail capacity constraint so that employers can better understand the potential impact of rail congestion on their businesses.
3. To act as an input to the PETE[3] method for estimating the agglomeration dis-benefits and productivity shocks associated with urban rail constraint. The productivity shocks in turn act as an input to the TERM[4] model (Chapter 8).

[3] As highlighted in Chapter Three, this refers to the method adopted by the UK Department of Transport (2009) and the New Zealand Transport Agency (2008).

[4] TERM stands for The Enormous Regional Model which was used in this research; TERM is the name given to the Computable General Equilibrium model by its creator at the Centre of Policy Studies, Monash University (Horridge et al., 2005).

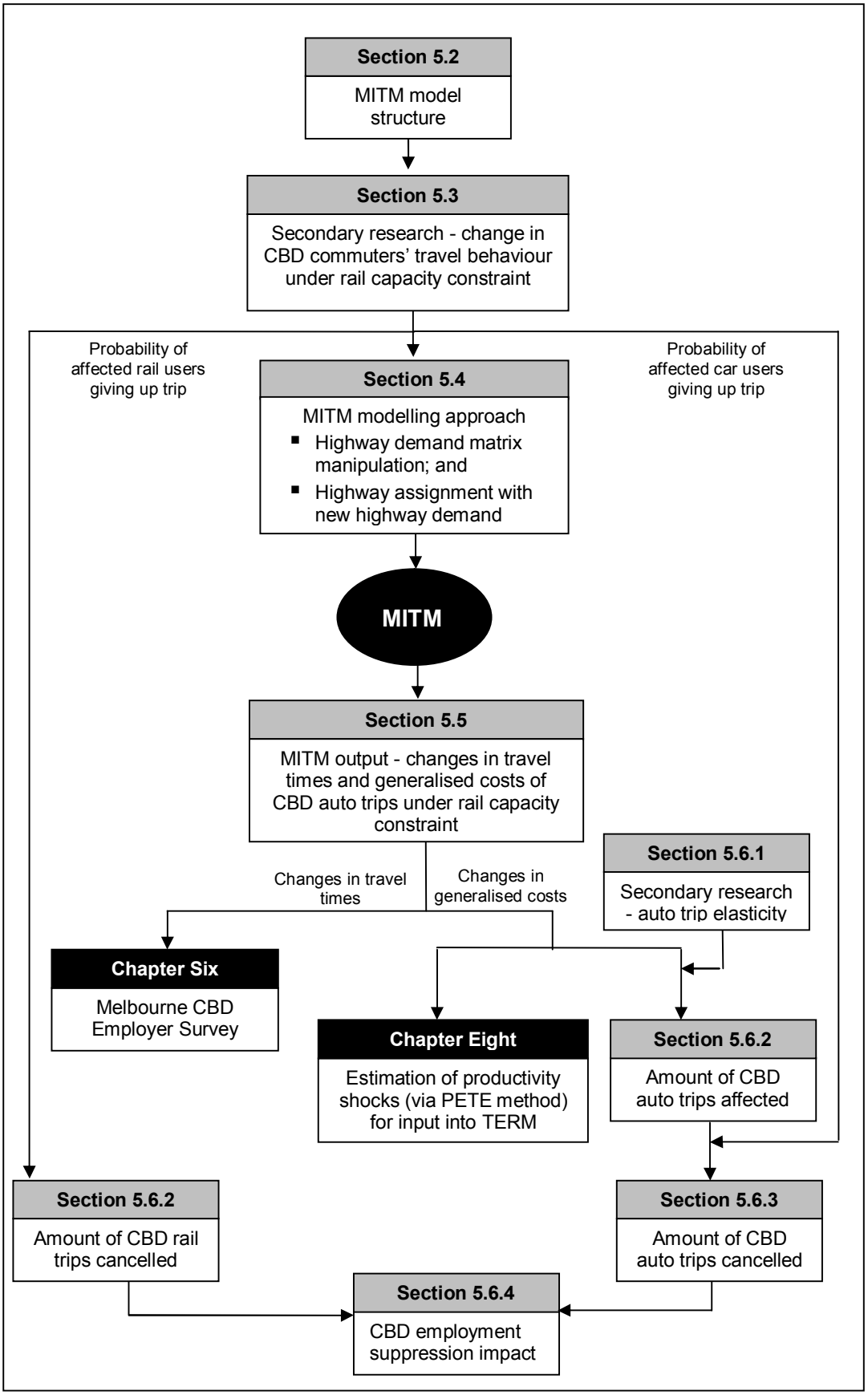


Figure 5.2: Overview of the MITM modelling framework

This chapter is structured in the following order.

- **Section 5.2 -** **Overview of MITM** introduces MITM's model structure, modelling process and outcome.
- **Section 5.3 -** **Secondary research: CBD Commuter Behaviour and Rail Capacity Constraint** presents the secondary research of how the travel behaviour of CBD employees may change under situations of rail capacity constraint.
- **Section 5.4 -** **MITM Modelling Approach** details the transport modelling approach adopted in this research.
- **Section 5.5 -** **Analysis of MITM Output** presents the findings of the transport modelling outcome.
- **Section 5.6 -** **Assessment: Employment Suppression Impact** estimates the potential employment suppression impact associated with rail capacity constraint using MITM's output.
- **Section 5.7 -** **Summary** concludes the chapter.

5.2 Overview of MITM

MITM is a traditional four-step transport demand model that is developed on the CUBE / TRIPS[5] platform. The salient features of MITM are outlined here; the detailed documentation of MITM can be found in DOT (2008c). The section begins with an introduction of MITM's model structure followed by an overview of its simulation process and outcome.

5.2.1 MITM Model Structure

Basically, MITM consists of four components, namely:

1. a demand model
2. a transport network model of Metropolitan Melbourne
3. a road assignment model
4. a public transport (PT) passenger assignment model.
   (DOT, 2008c)

The MITM network is made up of 2,272 transport zones and 35,700 links which represents the highway network (i.e. freeways, arterials, collectors) and PT network (i.e. tram, rail and bus routes) (DOT, 2008c).

According to DOT (2008c), MITM is able to model the following time periods.

- AM peak (7am to 9am).
- 2 hour inter peak representative of average travel patterns in the period between 9am and 3pm[6].
- PM peak (4pm to 6pm).
- 24 hour.

[5] CUBE / TRIPS are transport modelling software developed by Citilabs.

[6] DOT (2008c) explains that the inter-peak period ends at 3pm rather than 4pm as the PM peak in Melbourne has been observed to begin around 4pm; in addition, a large proportion of trips between 3pm and 4pm are made by school students and hence may not be representative of the average travel patterns.

MITM uses eight trip purposes for home-based trips and six trip purposes for non-home based trips as shown in Table 5.1.

Table 5.1: Trip Purposes in MITM

Home-based trip purposes	Non home-based trip purposes
Home-based work (white collar)	Work-based work
Home-based work (blue collar)	Work-based shopping
Home-based education (primary, secondary, tertiary)	Work-based other
Home-based shopping	Shopping-based shopping
Home-based work recreation	Shopping-based other
Home-based other	Non-home based

Source: DOT (2008c)

The travel demands for MITM have been developed from the following sources.

- Transport Research Centre (TRC) (1999) VATS 1994 – 1997 data
- Australian Bureau of Statistics (ABS) 1996 journey-to-work survey data
- ABS 1996 census data for population, household and car ownership data
- School enrolment data
- Market and travel segmentation curves and associated calibration coefficients, as used in the Scoresby Corridor Environment Effects Statement.
  (DOT, 2008c)

DOT (2008c) highlighted that the base MITM model has been calibrated[7] using the 1996 VATS data. They also highlighted that the MITM has been validated based on the following data.

- 1996 traffic count data across 20 screenlines (which comprise 850 survey locations throughout Metropolitan Melbourne).
- 1996 Melbourne train loading data at key stations on 31 services.
- 1996 survey data for 179 bus routes across Melbourne metropolitan area.

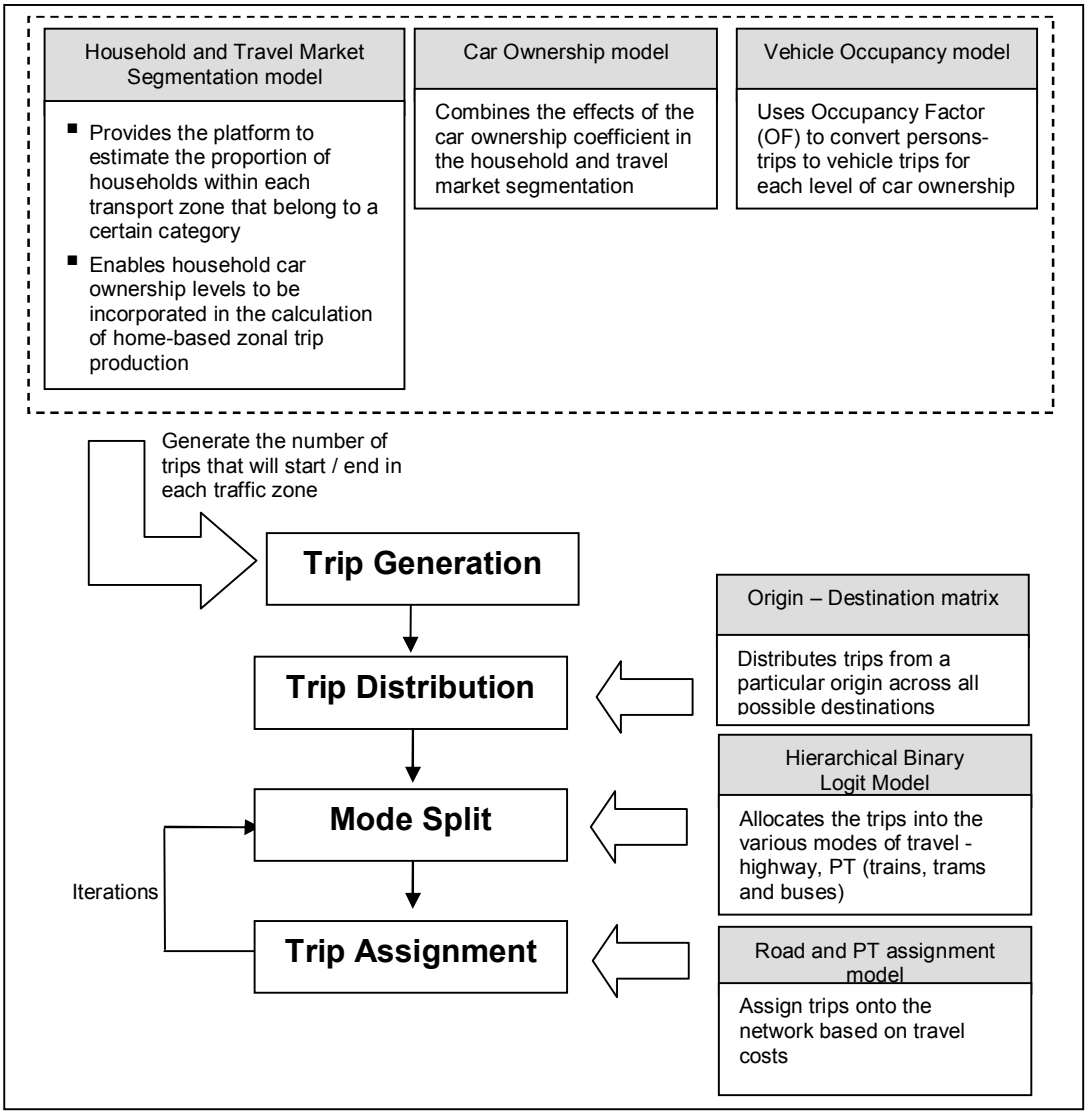
[7] DOT commissioned Sinclair Knight Merz and AECOM to recalibrate the MITM model in the beginning of 2009; the recalibrated MITM is anticipated to be ready for use in 2010 / 11 financial year (DOT, 2010). The MITM modelling in this research was carried out in late 2008 / early 2009.

5.2.2 Modelling Process and Outcome

The modelling process and outcome of the MITM is illustrated in Figure 5.3. As highlighted earlier, the simulation process of MITM comprises the following four steps.

1. Trip Generation
2. Trip Distribution
3. Mode Split
4. Trip Assignment.

The following section briefly discusses the four-step modelling process. A general overview of this modelling approach is given in Ortuzar and Willumsen (2001).



Source: Developed from DOT (2008c)

Figure 5.3: MITM Simulation Process and Outcome

5.2.2.1 Trip Generation

Trip generation is the first step in the MITM travel demand modelling process. This step provides the mechanism for MITM to determine the number of persons or vehicular trips generated by and attracted to each Transport Analysis Zone (TAZ). The trip demand model consist of two sub-models namely the trip production model and the trip attraction model.

The trip production model predicts the average number of weekday person trips produced by households within each TAZ for each trip purpose. The trip purposes adopted in MITM were shown in Table 5.1. The trip production model utilises a series of additive linear relationships for each trip purpose to estimate the number of person trips made by households of varying characteristics within each TAZ. The household characteristics were defined in MITM by a set of stratified variables within seven attribute groups including family size, vehicle ownership, number of white-collar residents, number of blue-collar residents, number of dependent residents aged 0-17 years-old, number of dependent residents aged 18-64 years-old and number of dependent residents aged 65 years-old and above. The linear relationships are represented by Equations 5.1 and 5.2.

$$HPT_{purp} = a_0 + SAG_1 + SAG_2 + ... + SAG_n \qquad \text{(Equation 5.1)}$$

where

- HPT_{purp} are the weekday person trips by a household for a particular purpose
- a_0 is the calibration coefficient
- $SAG_{1\ to\ n}$ are the stratified household attribute groups.

Each SAG is itself an additive linear function of the following format:

$$SAG_n = c_0 ATT_0 + c_1 ATT_1 + c_2 ATT_2 + ... + c_n ATT_n \qquad \text{(Equation 5.2)}$$

where

- SAG_n are group of household attributes described above
- $C_{0\ to\ n}$ are the calibration coefficients
- $ATT_{1\ to\ n}$ are the dummy variables representing the level of a particular attribute level for example, ATT_n = 1 if household size is equal to n, otherwise ATT_n = 0.

The calibration of MITM carried out by DOT was achieved through identifying the relationship between the zonal trip production variables and observed types of trips made from the VATS data (TRC, 1999). This was performed using a stepwise linear regression model where the number of trips made by each TAZ for each trip purpose for the various household characteristics was expressed as a linear function of the household attributes. The summation of trips for various household characteristics provided the total number of trips generated by each TAZ for each trip purpose.

The trip attraction model predicts the average number of weekday person trips attracted to each TAZ for each trip purpose. Similar to the prediction models, the attraction model also utilises a series of linear additive relationships represented by Equation 5.3. The zonal trip attraction variables include population size, number of households, education enrolments, employment by industry types as well as the total number of white and blue collar workers employed in each TAZ.

$$ZPTA_{purp} = a_0 + a_1 ZTAV_1 + a_2 ZTAV_2 + ... + a_0 ZTAV_n \qquad \text{(Equation 5.3)}$$

where

- $ZPTA_{purp}$ are the weekday person trips made to a zone
- $a_{0\ to\ n}$ are the calibration coefficients
- $ZTAV_{1\ to\ n}$ are the zonal trip attraction variables described above.

The calibration of the trip attraction model was achieved through identifying the relationship between the zonal trip attraction variables and observed types of trips made from Census data and Journey-to-work data from ABS. This was carried out using a stepwise linear regression model in which the number of trips attracted to each TAZ for each trip purpose was expressed as a linear function of zonal attraction variables. The selection of the zonal trip attraction independent variables for a particular trip purpose was based upon the best fit of the observed data.

The final step in the demand modelling is the balancing of the urban area-wide trip productions and attractions. The area-wide production and attraction totals are not exactly equal as the trip productions and attractions are estimated separately. The area-wide control totals for all trip purposes are set to equal to trip productions. The balancing process was accomplished by applying a balancing factor to the attraction trips so that the total number of attractions equals the total number of productions. The balanced productions and attractions were used for the trip distribution phase of the modelling process.

5.2.2.2 Trip Distribution

Trip distribution is the second step in the MITM modelling process. Trip distribution enables trips from a particular origin to be distributed across all possible destinations according to a travel demand pattern. This pattern was predicted according to the probability Gamma function that reflects the travellers' perception of the cost of travel and the relative attractiveness of the intended destination. The Gamma function is represented as follows.

$$T_{ij} = a_i b_j P_i A_j C_{ij}^{\alpha} e^{\beta C_{ij}} \qquad \text{(Equation 5.4)}$$

where

- T_{ij} is the estimated number of trips from zone *i* to zone *j*
- P_i is the number of trip productions from zone *i*
- A_j is the number of trip attractions to zone *j*
- a_i and b_j are row / column balancing factors
- $C_{ij}^{\alpha} e^{\beta C_{ij}}$ is the cost deterrence function from zone *i* to zone *j*
- C_{ij} is the generalised cost from zone *i* to zone *j*
- e is the base of natural logarithm
- α and β are calibration coefficients.

The first step in obtaining the trip distribution model in MITM is to calculate the generalised cost for each origin-destination (O-D) pair. Given that overall motorised travel is dominated by car trips, DOT decided to adopt the car travel times for this purpose in MITM. This was achieved by loading a highway O-D matrix onto the road network and cost skimming each path for time and distance. The final generalised cost matrix is obtained by factoring the weighted time and distance skim matrices by 18.15 cents per minute and 14.35 cents per kilometre respectively; these parameters represents average per person costs (DOT, 2008c).

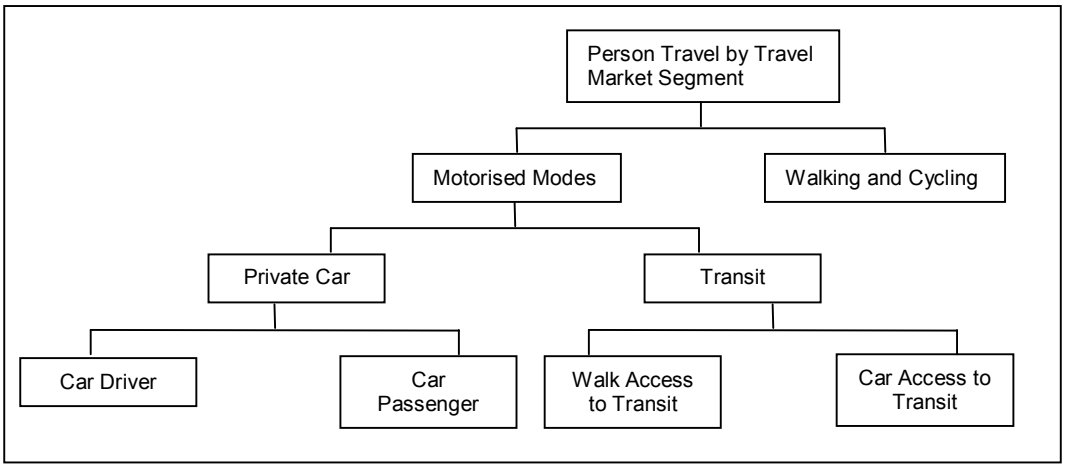
Observed trip records for each trip purpose were extracted from the VATS database. These were used to build observed partial trip matrices with a limited number of O-D pairs for the eight home-based and six non-home based trip purposes. Each observed partial matrix along with the generalised cost matrix were utilised to calibrate the Gamma function coefficients alpha (α) and beta (β) for each trip purpose. The calibrated coefficients were then used to distribute the trip ends produced by the Trip Production and Trip Attraction models to yield the 14 trip purpose matrices.

A series of manual alterations were subsequently made to the Gamma function coefficients until acceptable matching results were obtained between the estimated and observed mean trip lengths and between modelled and surveyed screenline volumes and transit patronage figures.

5.2.2.3 Mode Split

The third step in the conventional 4-step modelling approach is the mode split analysis. In this step, the total zone-to-zone person trips resulting from the trip distribution model are split into trips using each available travel mode between each O-D pair. This is carried out by considering the service characteristics (such as travel time, costs etc) of the modes available for the given trip purpose to determine the modal split.

This is the typical mode split approach for urban areas where the competition between private transport, public transport and other modes of travel is considered explicitly. In MITM, this is carried out using a hierarchical (or nested) binary logit model as shown in Figure 5.4.



Source: DOT (2008c)

Figure 5.4: Mode split structure in MITM

The structure allows a series of binary choices with the results of one choice leading to further choices. According to DOT (2008c), each choice is calculated using a logit function as shown below.

$$P_2 = \frac{1}{1 + e^{(C_2 - C_1 + \delta)}} \qquad \text{(Equation 5.5)}$$

where

- P_2 is the probability of choosing mode 2
- C_1 is the generalised cost for mode 1
- C_2 is the generalised cost for mode 2
- δ is the perceived costs that have not been included in the model's estimates of zone to zone travel costs.

The mode split functions were calibrated using all trips recorded in VATS for each purpose.

5.2.2.4 Trip Assignment

Trip assignment is the final step in the traditional four-step travel demand modelling process. In this fourth step, the predicted modal flows between each O-D pair are assigned to actual routes across the given mode's network in MITM. The assignment of trips to each mode's network forms the basis for validating MITM's ability to replicate observed travel in the base year. The level of the precision of the assignment procedure is dependent on the level of detail each mode's network is coded and the size of the associated zone system.

As the base year in MITM represents 2006 (DOT, 2008d)[8], separate networks were prepared to reflect the 2006 conditions for the public transport and highway networks. According to DOT (2008c), the overall PT network includes all services on the metropolitan passenger train lines (both express services and services that stops at all stations), services for all tram routes, services for all bus routes, park and ride facilities, links to reflect walk access to services including interchanges and the road network private vehicle travel. The highway network is based on the latest version of TRIPS Melbourne Strategic Highway Model (MSHM), which represents the 2006 highway network serving the entire Metropolitan Melbourne area.

Motorised public transport matrices are combined to provide a single purpose person trip matrix for assigning to the public transport network. Car based person trips matrices are factored by vehicle occupancy factors and the matrices are then combined to produce a car trip matrix. The car trip matrix is assigned to the highway network using an equilibrium assignment process. Multi-volume delay formulations in the form of speed-flow curves varying by facility types were applied to the highway assignment algorithm. Equilibrium assignment techniques explicitly recognise that transport link costs generally depend on the volume using that link.

This final step uses an iterative process to establish convergence of mode split between successive iterations as highway cost skims are modified by levels of congestion on the network. The degree of convergence is defined by specifying the gap statistic. The gap statistic represents the difference between all trips using the current minimum cost route and the vehicle loading pattern obtained so far in the iterative cycle.

[8] Obtained via personal communication.

As part of the validation check, the modelled highway traffic volumes were validated against 2006 traffic counts on a screenline basis. The checks showed that the modelled highway traffic volumes were within 1% of the surveyed volumes in the peak direction and 13% in the off-peak direction. As for PT, modelled train ridership was within 20% of the surveyed loadings and modelled bus patronage was within 16% of the surveyed bus ridership[9].

5.3 Secondary Research – CBD Commuter Behaviour and Rail Capacity Constraint

MITM is a traditional four-step transport demand model which estimates the desired travel demand on various PT modes and the highway network under different transport scenarios. However, it contains no modelling of capacity constraints - i.e. MITM is not able to redistribute the surplus travel demand on a particular PT mode, which has already reached capacity, to other modes where capacity is still available. Therefore, prior to the actual MITM modelling of an urban rail constraint, secondary research was conducted to investigate how CBD employees are likely to change their travel behaviour in circumstances of a rail capacity constraint. The findings which are presented here are needed to make appropriate assumptions in the application of the MITM model.

The secondary research revealed that there is no previous study that strictly examined how the accessibility of CBDs is affected when the passenger rail capacity serving them is constrained. While there were limited studies that looked at the closures of rail systems, such as Taylor (2006) and Patmore (1966), these studies focused largely on the physical extent of the rail closures, with general qualitative discussion on the associated social consequences. No detailed information pertaining to impact on user behaviours was presented.

Studies regarding PT strikes, such as the work of Coindet (1998), Blumstein and Miller (1983) and Wegmann et al. (1979) may offer some indication on the potential impact of an urban rail capacity constraint on commuter travel behaviour. These studies are, however, very scarce, because strikes are not easily anticipated and may also not last long enough to allow for an appropriate study design and realisation (Exel and Rietveld, 2001).

[9] According to DOT (2008c), the modelled train patronage on the majority of lines are less than surveyed patronage. On the other hand, DOT (2008c) highlighted that MITM is over estimating bus patronage.

Relevant information was found in the work of Exel and Rietveld (2001), which reviewed 13 past studies on PT strikes that took place between 1966 and 2000 in Europe and the United States. They concluded that necessary trips such as commuting to work or school are potentially the most significantly affected by any disruption in PT provision. Table 5.2 summarises their findings.

Table 5.2: Impacts of public transport strikes[10]

Location	Year	Spatial scale	PT modes affected (%)	Trips switched to automobile mode		Trips switched to other alternatives (%)	Trips cancelled (%)
				Driver (%)	Passenger (%)		
New York	1966	Urban	All	50	17	23	10
Leeds	1978	Urban	All	5	60	20	15
The Hague	1981	Urban	All	10	25	50	15
Ile-de-France	1995	Regional	All	28	21	40	11
Holland	1995	National	Bus	5	25	60	10
Average				**19.6**	**29.6**	**38.6**	**12.2**

Source: Exel and Rietveld (2001)

Exel and Rietveld (2001) suggested that the automobile mode is the most preferred mode choice of the affected PT users. As shown in Table 5.2, about 50% of affected PT users were likely to switch to the automobile mode either as a driver (average 19.6%) or passenger (average 29.6%). Exel and Rietveld (2001) explained that the strong preference of the automobile mode as the alternative choice was within expectation, as those affected commuters residing in inter-urban areas would probably not have many alternative mode choices - mostly the private automobile or alternative public transport if available, i.e. bus instead of rail, are the only options remaining.

The findings of Exel and Rietveld (2001) also suggested that on average about 38% of the affected PT users may potentially switch to alternatives including walking, cycling and private buses arranged by employers. Similar to the findings of Mackett (2001), their work also indicated that these alternatives are only viable options for those affected PT users who live in urban areas or near to their destinations.

[10] Only public transport strikes with complete data as shown in Exel and Rietveld (2001) are reflected here; this is to facilitate the subsequent analysis.

Exel and Rietveld (2001) also highlighted that there is a segment of captive PT users that will not have alternatives. This group of captive PT users would largely include the elderly, the disabled, young people who are not able or permitted to drive and those who have no access to automobiles. Exel and Rietveld (2001) estimated that the group of captive users would result in the cancellation of about 12% of trips on average when PT provision is disrupted.

The secondary research also found evidence on possible changes of rail users' behaviour under circumstances of rail capacity constraint in the work that HLB Decision Economics Inc (2003) did for the State of Wisconsin Department of Transportation. In this study, HLB captured the alternative modes that PT users would use for their work trips[11] or other non-transport choices (including giving up of employment) that they may make in the absence of transit services[12]. The broad similarities between the State of Wisconsin, USA and Victoria State, Australia (where Melbourne metropolitan area is located) in terms of (2006) population and employment demographics as well as vehicle population suggests that the findings of HLB (2003) may provide some insight into the change in travel behaviour of Melbourne PT users in situation of rail constraint – see Table 5.3.

Table 5.3: Demographics and vehicle population of Wisconsin State and Victoria State (2006)[13]

Parameter	State of Wisconsin (USA)	State of Victoria (Australia)
Population (mil)	5.5	4.6
Employment (mil)	2.7	2.4
Vehicle population (mil)	5.3	4.6

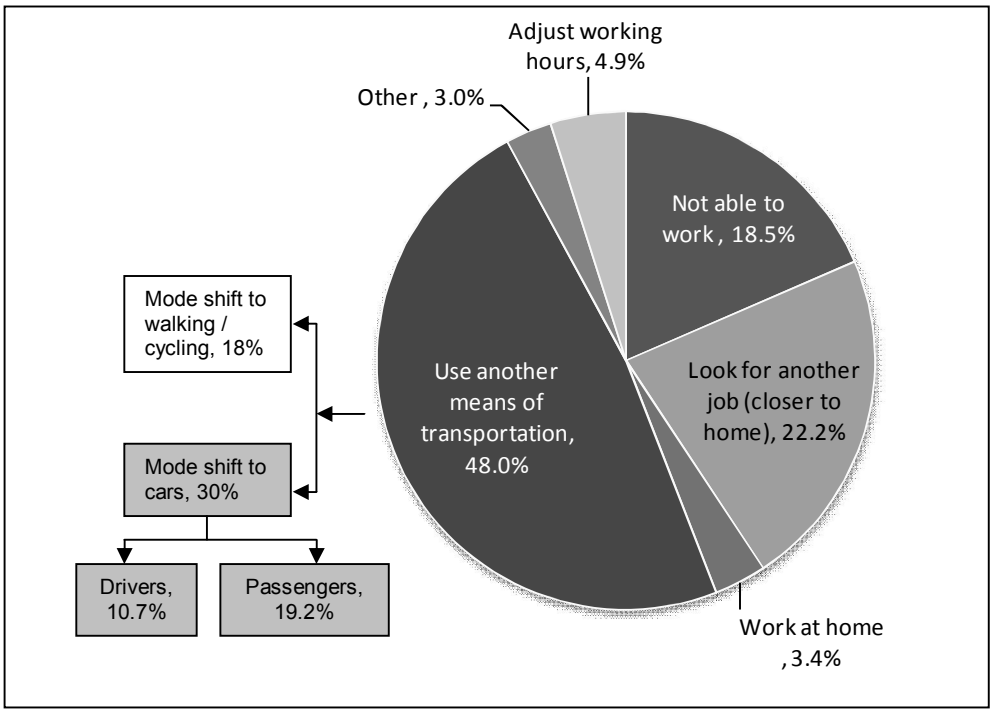
Source: State of Wisconsin (2008), Wisconsin Department of Transportation (2008), ABS (2006a) and VicRoads (2008b)

[11] HLB's (2003) study covered trips related to work, education, healthcare and recreational purposes. In view of the purpose of this research, this research focuses largely on their findings pertaining to work trips.

[12] These include both the buses and passenger rail services which represented the PT network in the State of Wisconsin.

[13] For consistency with the ABS data, the Wisconsin figures reflected here are interpolated to 2006 level.

HLB's (2003) findings for work trips are summarised in Figure 5.5. As shown in the figure, 48% of the surveyed respondents indicated that they would still make the same work trip via an alternative mode should their transit be unavailable. 33.5% of the respondents indicated that they would choose a non-transport related alternative (such as look for another job closer to home, relocate closer to work place or adjust working hours), while the remaining 18.5% indicated that they would cancel their work trips.



Source: based on analysis of HLB (2003)

Figure 5.5: Alternative choices for work trips in the absence of transit

Of the 48% of the respondents that indicated that they would still make the same work trip via an alternative transportation mode, HLB (2003) estimated that about 30% would shift to the automobile mode (10.7% as driver and 19.2% as passenger) while the remaining 18% would shift to other alternatives including walking (9.5%), cycling (7.2%) and other PT modes (1.3%).

Relevant information was also found in Litman (2008) who reported that surveys conducted by the Transit Performance Monitoring Systems (TPMS) found that about 51% of respondents may switch to an automobile mode, 28% may consider other alternatives including walking and cycling while 21% may give up their trip if transit services were unavailable – see Table 5.4.

Volusia County Public Transit also carried out an on-board survey (cited in Litman, 2008). Their survey findings, also shown in Table 5.4, suggested that about 54% of the affected transit users may mode shift to automobile use while 14% of them may cancel their trips.

Table 5.4: Results of travel behaviour surveys from TPMS and Volusia County Public Transit

Survey	Year	Trips switched to automobile mode		Trips switched to other alternatives (%)	Trips cancelled (%)
		Driver (%)	Passenger (%)		
TPMS	2002	23	28[14]	28	21
Volusia County Public Transit	1999	8	46	32	14
Average		**15.5**	**37.0**	**30.0**	**17.5**

Source: Litman (2008)

It is observed that the estimated percentages of mode shift to cars and other modes estimated by Exel and Rietveld (2001) and Litman (2008) is on average about twice that of HLB's (2003); on the other hand, the percentages of trips cancelled estimated by Exel and Rietveld (2001) is about two-thirds in magnitude of those shown in Figure 5.5. This significant variation in estimation is due to the non-transport related alternatives considered by HLB (2003), which accounted for some 50% of the respondents. Studies that examined past PT strikes and the surveys cited in Litman (2008) collected limited or no data on non-transport related choices.

Despite significant differences in context for the evidence presented above, the sets of evidence showed some consistency. Both sets of information suggest that, of the affected PT users who would still make the same work trip, there is an approximately 60% probability that they would shift to the automobile mode (either as a driver or passenger), while the probability of them choosing walking, cycling or other PT modes as the alternative mode is about 40%. This consistency was also noted by Litman (2008, page 51) who highlighted that "other surveys find similar results". The fact that this consistency transcends geographical boundaries suggests that it is reasonable to expect Melbourne CBD rail commuters to also behave in the same manner under circumstances of urban rail constraint. This is especially since VATS data analysis carried out in Section 4.3.3.4 suggests that rail users are most likely to mode shift to car use in an event of a rail capacity constraint.

[14] Estimated by assuming that half of the 12% of the respondents that indicated a possible shift to the taxi / train option will eventually mode shift to taxi; the other 6% is assumed to mode shift to train and is included in the "trips switched to other alternatives" total.

It is also observed that the potential HLB trip suppression impact of 18.5% is much higher than that found in Exel and Rietveld (2001) but close to the 17.5% estimated from the work of Litman (2008). This is possibly because the cancelled trips as reported in Exel and Rietveld (2001) included trip types other than work trips. For comparative purpose, if trips related to other purposes such as education and healthcare were considered, HLB's (2003) results suggested that the trip suppression impact in the absence of transit provision is about 11.5% (see Table 5.5). This is close to the average figure of 12.2% estimated using data from Exel and Rietveld (2001).

Table 5.5: The potential trip suppression impact for various trip purposes if public transport was withdrawn

Journey Purpose	Reason for cancelling trips	Trips cancelled (%)
Work	Not able to work	18.5
Education	Not able attend school	12.6
Healthcare	Receive home care	5.8
Shopping and Recreation	Shop online or by catalogue	9.1
Average		**11.5**

Source: HLB (2003)

5.3.1 Assessment – Alternatives for Work Trips in times of Rail Capacity Constraint

Based on the above secondary research, an assessment was undertaken to estimate the following.

- The probability that Melbourne CBD rail commuters would cancel their work trip or shift to the car mode in times of rail capacity constraint.
- The probability that Melbourne CBD car users would cancel their work trip as they are "priced out" by the higher cost of automobile trips due to the rising traffic congestion.

These data are necessary inputs for the MITM modelling and the estimation of employment suppression and productivity impact as explained in the following discussion.

5.3.1.1 Alternative Choices for Affected Rail Commuter Trips

The secondary research carried out earlier found evidence from past studies on PT strikes and the work of HLB (2003) which suggests that there is some consistency in mode shift patterns of affected transit users. As there is no published information of similar studies carried out in Metropolitan Melbourne, this research adopted HLB's (2003) findings to assess the change in travel behaviour of affected rail users under an urban rail capacity constraint scenario.

The rationale to adopt HLB's (2003) findings as the basis of assessment is as follows.

- The broad similarities between the State of Wisconsin, USA and Victoria State, Australia in terms of (2006) population / employment demographics and vehicle population suggests that the findings of HLB (2003) may provide some insight into the possible change in travel behaviour of Melbourne PT users in situation of rail capacity constraint.

- HLB's (2003) work which offered non-transport related alternatives (such as look for another job closer to home, relocate closer to work place or adjust working hours) to the surveyed commuters would better reflect the possible reaction of the affected rail users in reality over a longer period of time say 1-2 years or more. Comparatively, those studies that examined travel behavioural changes during PT strikes may only illustrate how commuters would react during the strike period, which usually does not last more than a couple of days or weeks. The former should give a more realistic indication of how Melbourne commuters may react to rising rail congestion.

- The inclusion of "look for another job" option as one of the non-transport related choices would mean that the potential employment suppression impact estimated based on HLB's (2003) findings would not have included the employment which may flow-on to other regions. This addresses the general concern that agglomeration benefits associated with transport improvement are double-counting and re-distributive in nature – in this context, the estimated CBD employment suppression impact would not have "double-counted" any increase in employment (and hence agglomeration benefits) elsewhere.

- The lower trip cancellation impact of 12.2% as estimated by Exel and Rietveld (2001) included non-work trip purposes, which may dilute the potential suppression impact to work trips. This distortion may be more substantial in the AM peak hour since work trips account for the majority of trips (83% of peak hour trips - VATS data (TRC, 1999)).

For this exercise, the employment suppression impact estimated in Section 5.6.2 only consider the 18.5% of trips that may potentially be cancelled as based on HLB (2003). This is to derive a conservative estimate of the potential employment suppression impacts. The 22.2% under the "look for another job" option are not considered to avoid over-estimating the potential employment suppression impacts (and hence the agglomeration diseconomies) associated with an urban rail constraint. This concern is explained further in the next paragraph.

Section 4.2.2 reported that Addario and Patacchini (2006) found that agglomeration effects occur within local labour markets of up to 12km in radii on average while Rice et al. (2006) concluded that increasing the size of the working population located within an hour's journey time will still have agglomeration impact on the local employment centre's productivity. Their findings on the decay effects of agglomeration impact suggest that the 22.2% of affected rail users that may look for alternative employment elsewhere should the CBD's accessibility deteriorates, may still be "contributing" to the agglomeration effects of the CBD. The case for this is stronger based on the assessment carried out in Section 4.2.2 which suggests that some of the knowledge-based employment may have spilled over or relocated over from the CBD into surrounding areas within 10km from the CBD. In any case, these 22.2% of affected rail users are contributing to the agglomeration effects of the region where their new firms are located. Therefore, to avoid "double-counting" the same agglomeration effects, this exercise also does not include this 22.2% in the estimation of the potential employment suppression impacts.

HLB (2003) also suggests that the weighted probability of an affected CBD employee shifting from rail to the automobile mode is about 30% - i.e. 10.7% as driver and 19.2% as passenger. Assuming that half of the trips which involve chauffeuring would result in a new automobile trip, it is estimated that a constraint in the rail capacity provision can lead to a 20.3% shift of the affected rail trips into a new car trip on the highway network. For example, in a scenario where the rail demand exceeds the rail capacity provision by 10% (i.e. a 10% rail capacity constraint scenario), 10% of those commuters who wish to board the train would not be able to do so. Based on the above assumption, out of these 10% affected train users, 2% are likely to generate a new car trip. Assuming that the relationship is linear, every 10% increase in rail capacity constraint will cause an additional 2%[15] of affected rail trips resulting in a new car trip. The above assumption essentially "converts" the diverted rail passenger trips to car trips. This is to be compatible with the highway demand matrix for MITM modelling - Section 5.4 explains how these percentages are used in MITM modelling.

[15] While Section 5.2.2.4 (footnote 3) highlighted that MITM underestimates rail patronage, this research did not factor up this 2% of diverted rail-to-car trips. This research "compensated" for MITM's lower rail patronage estimation by considering all rail trips in the AM peak rather than only the CBD bound rail trips (which made up 90% of the former (Connex Melbourne, 2009)) in the MITM modelling – see Section 5.4, footnote 12. This modelling assumption has the added advantage of simplifying the MITM modelling.

5.3.1.2 Alternative Choices for Affected Auto Commuter Trips

As explained earlier, an increase in rail congestion can lead to a 20.3% shift of the affected rail trips into a new car trip on the highway network. The rise in traffic volume on the highway network is expected to increase the generalised cost of travel by car into the CBD during the AM peak. As will be shown in Section 5.6, evidence from trip elasticity studies suggest that the increase in generalised cost is likely to "price out" some of the existing car users (either as driver or passenger) who would give up their car trips into the CBD.

In this instance, the probability (P^C) of affected CBD car users to shift to other transport and non-transport alternatives under an urban rail capacity constraint are estimated by adjusting HLB's (2003) findings (P^C_{HLB}) using the equations shown in Table 5.6 where *C* represent the other alternative transport modes or non-transport choices. Table 5.7 describes the variables and coefficient in these equations.

For this assessment, mode shift to other PT alternatives (i.e. the tram and buses) as well as walking and cycling was assumed to be not an option for those affected car users who are located beyond 10km from the CBD. This assumption is reasonable as the findings of Currie and Senbergs (2007) suggested that tram and bus provision is low for those areas located beyond 10km from the CBD (see Figure 4.15) and in this project context, the rail system was taken to be congested. Therefore, the affected car users in these areas are essentially left without a viable PT alternative. On the other hand, as explained in Section 4.3.3, given their distance from the CBD, walking and cycling are not attractive alternatives for this group of car users.

For those CBD employees that reside within 10km from the CBD, walking, cycling and the tram are considered to be viable and attractive options. This assumption regarding the availability of alternative modes of travel is governed by coefficient λ in the equations shown in Table 5.6. This coefficient is set to the value of 1 for those car users who reside within 10km from the CBD and 0 for those who reside beyond 10km from the CBD.

The resultant probabilities adjusted from HLB (2003) are shown in Table 5.8.

Table 5.6: Equations to estimate the probabilities of affected CBD auto users to shift to other alternatives

Equations
Equation 5.6: Probability to shift to other modes (*OM*) including walk, cycle or tram(P^{OM}) $$P^{OM} = \lambda * P_{HLB}^{OM} * (1 + [\frac{\{P_{HLB}^{car} + P_{HLB}^{carpax} + (1-\lambda) * P_{HLB}^{OM}\}}{\sum_{revised} P_{HLB}^{affectedcar}}])$$
Equation 5.7: Probability to make non-transport choices (*NTC*) (P^{NTC}) $$P^{NTC} = P_{HLB}^{NTC} * (1 + [\frac{\{P_{HLB}^{car} + P_{HLB}^{carpax} + (1-\lambda) * P_{HLB}^{OM}\}}{\sum_{revised} P_{HLB}^{affectedcar}}])$$
Equation 5.8: Probability to cancel trip (*CT*) (P^{CT}) $$P^{CT} = P_{HLB}^{CT} * (1 + [\frac{\{P_{HLB}^{car} + P_{HLB}^{carpax} + (1-\lambda) * P_{HLB}^{OM}\}}{\sum_{revised} P_{HLB}^{affectedcar}}])$$
Equation 5.9: Summation of probability for affected car users[16] $$\sum_{revised} P_{HLB}^{affectedcar} = \lambda * P_{HLB}^{OM} + P_{HLB}^{NTC} + P_{HLB}^{CT}$$

Table 5.7: Variable descriptions

s/no	Variable name	Description
1.	P^c	Adjusted probability.
2.	P_{HLB}^c	Corresponding probability from HLB (2003).
3.	C	Stands for other alternative transport modes or non-transport choices namely: - ▪ MO = other modes; ▪ NTC = non-transport choices; and ▪ CT = cancel trip.
4.	λ	Coefficient that governs the availability of tram, cycling and walking: – ▪ 1 for car users who reside <10km from CBD; and ▪ 0 for car users who reside >10km from CBD

[16] Equation 5.9 sums the probabilities of affected car users to shift to other available modes or make alternative choices; this is needed as an input to Equation 5.6 – 5.8.

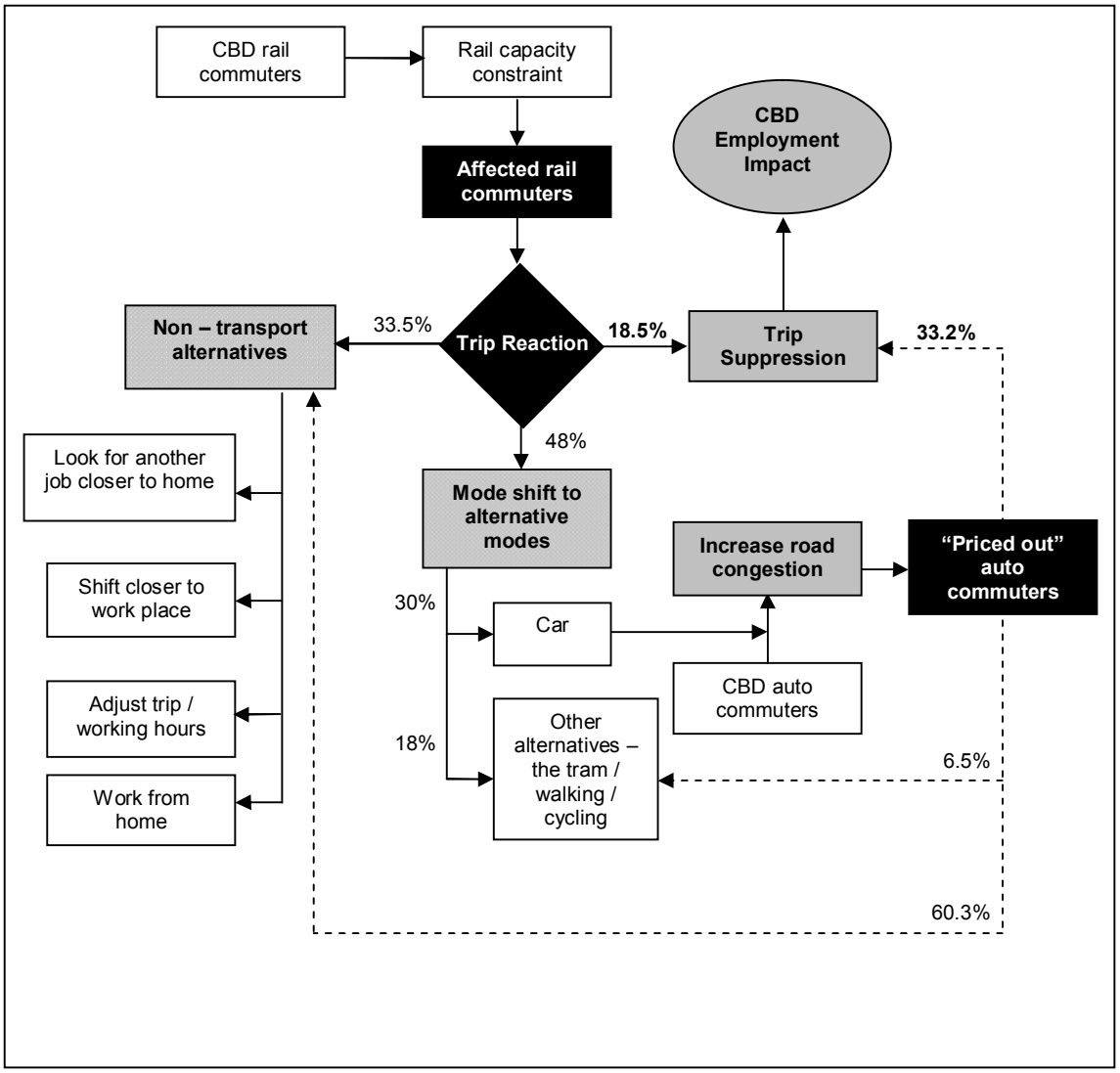
Table 5.8: Alternative choices for work-related automobile trips when rail capacity is constrained – adjusted from HLB (2003)

	Non-transport related choices (%)	**Mode shift to the tram / walking / cycling (%)**	**Give up trip (%)**
HLB (2003)	33.5	18.1	18.5
Employees who reside **<10km** from CBD	47.8	25.8	26.4
Employees who reside **>10km** from CBD	64.4	0	35.6
Weighted Average	60.3	6.5	33.2

As shown in Table 5.8, when the highway network is congested, the affected car users who decide to give up their trips have an estimated 60.3% probability (weighted according to the car ownership levels of CBD employees) of making a non-transport related choice. There is a 6.5% probability that they will switch to the tram, walk or cycle to their work destination. The results also suggest that there is a 33.3% probability that the "priced-out" car users may cancel their work trip and hence give up their CBD employment. This probability has been used to estimate the employment suppression impact of affected car users who gave up their car trip in Section 5.6.3.

In conclusion, under circumstances of rail capacity constraint, affected Melbourne CBD employees are expected to react as illustrated in Figure 5.6.

- About 33.5% of affected rail commuters are expected to make non-transport related choices such as look for another job closer to home.
- About 18.5% of affected rail commuters are likely to give up their trip and hence employment in the CBD.
- About 48% of the affected rail users are likely to shift to another mode. This comprises 30% of affected rail users which are likely to shift to automobile use and this is envisaged to increase the congestion level on the highway network.
- The increased traffic congestion is expected to affect the CBD auto commuters and may force some of them to make alternative choices for their work trips. Of those "priced out" car users, 60.3% are likely to make non-transport related choices while 33.3% are likely to give up their employment in the CBD.



Source: Developed from HLB (2003).

Figure 5.6: Possible trip reaction and impact in circumstances of rail capacity constraint

5.4 MITM Modelling Approach

This research uses MITM to run a spectrum of transport scenarios to illustrate how various degrees of rail accessibility constraint would affect the AM peak highway travel times into Melbourne CBD. As MITM contains no modelling of capacity constraint, this has been carried out by manipulating the AM peak highway demand matrix through the following 2 steps.

1. The diverted rail-to-car trips for various levels of rail capacity constraints were added to the base case highway demand matrix to yield a new AM peak highway demand matrix – as estimated earlier, every 10% increase in rail capacity constraint will result in a shift of 2% of the affected rail trips to create new car trips.

2. A Highway Assignment run in MITM was carried out with the new highway demand matrix - i.e.

New AM Peak Highway Demand Matrix (auto trips)	=	Base Case AM peak Highway Demand Matrix (auto trips)	+	X% of Base Case Train Demand Matrix (auto trips)

(Equation 5.10)

For example, to simulate the impact of a 20% rail capacity constraint in the AM peak, the Highway Assignment of MITM has been run with a new highway demand matrix which is the summation of all car trips across the overall Melbourne highway network and 4% of all rail trips[17] across the Melbourne train network in the Base Case (2006).

[17] 90% of rail trips in the AM peak occur in the peak direction heading towards the CBD (Connex Melbourne, 2009). However, the MITM modelling in this study uses all the rail trips in the AM peak. This is to "compensate" for the under-estimation of rail patronage in MITM. If both the 90% factor and the 20% underestimation of rail trips in MITM were considered, a 20% rail capacity constraint would result in 4.3% (i.e. 4.2%*90%*120%) of all rail trips diverting to car use. This is close to the 4% estimated above. Hence, the use of all rail trips in the MITM modelling is considered a reasonable assumption.

The MITM modelling approach does not model those "forced-out" rail trips that may shift to tram and bus. Secondary analysis of the carrying capacity of the tram and bus routes serving the CBD in the AM peak suggests that these modes have ample capacity to absorb the diverted rail users; they are not modelled in MITM as they are not anticipated to be significantly affected[18]. Hence, it is expected that the MITM testing via the highway demand matrix manipulation method outlined above is sufficient to yield a reasonable indication of the changes in the generalised cost of highway trips into the CBD due to rail capacity constraint.

A series of rail congestion scenarios have been tested in MITM. The results corresponding to 10% to 50% rail capacity constraint at incremental intervals of 10%[19] are presented in the next section.

[18] Metlink (2009) indicated that a total of 149 bus services and 372 tram services enter the CBD during 7-9am on a typical weekday in 2009. Napper (2007) suggested the average carrying capacity of buses (standing + seating) for a rigid and articulated bus in Melbourne is about 75 - 100 passengers while Cliché and Reid (2007) indicated that the average carrying capacity for a typical tram is 160 – 250 passengers. Using the lower limit of the carrying capacities, it is estimated that the tram and bus services can carry about 70,600 passengers in the AM peak. Based on information extracted from MITM, a total of about 32,000 bus and tram trips are made into the CBD during the AM peak today (2006) – DOT (2008c) reported that this is an over-estimation. It is therefore evident that there is ample capacity on the tram and bus system to absorb the diverted rail users.

[19] This range of rail capacity constraint and the 10% incremental interval was selected for presentation to facilitate the interpretation of MITM's outputs – see Section 5.5.

5.5 Analysis of MITM Output

Figure 5.7 shows the proportion of car trips that enter Melbourne CBD from origins of varying distance from the city center under the present situation (2006) and different scenarios of rail capacity constraint – the former is represented by the red curve while the various rail capacity constraint scenario are represented by the black and grey (in different shades and form) curves.

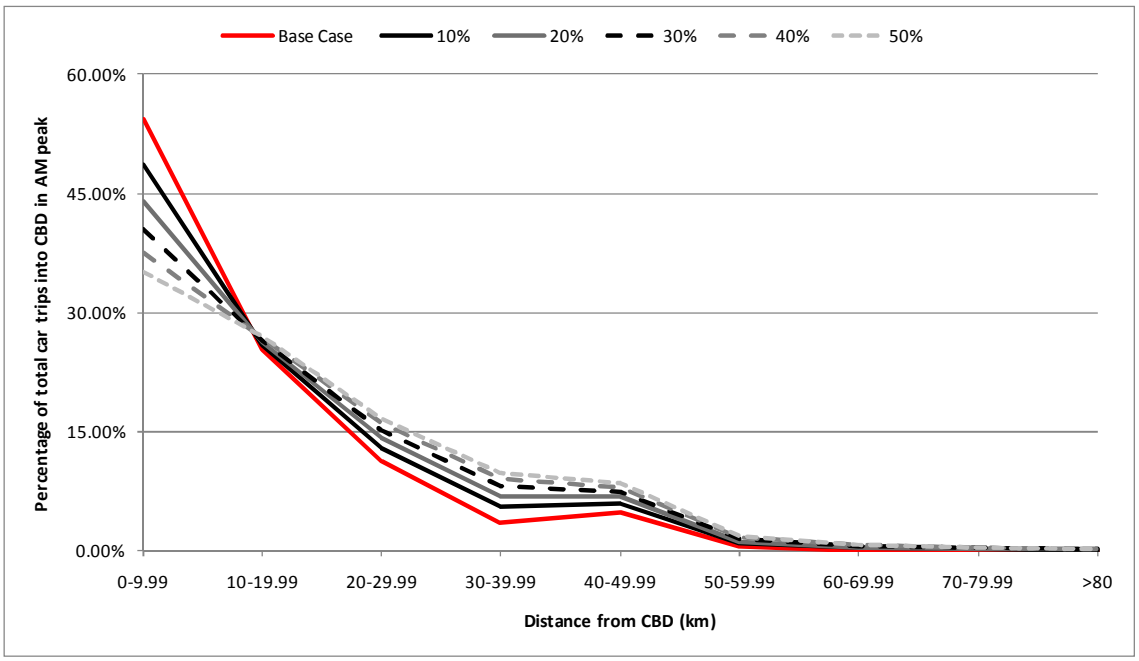


Figure 5.7: Proportion of car trips entering the CBD from various distant bands under different scenarios of rail capacity constraint in AM peak

The curves shown on Figure 5.7 indicates that as the level of rail congestion increases, the proportion of car trips that commence from within 10km from the CBD falls; on the other hand, the proportion of car trips from origins that is more than 10km away from the CBD rises as the level of rail capacity constraint increases. This supports the earlier argument that affected CBD employees residing within 10km from the CBD have more attractive options including walking, cycling and the tram. Therefore, when traffic congestion worsens, some of these workers may choose to give up their car trip and mode shift to these alternatives. For those that reside beyond 10km, such options are not available. Therefore, a higher level of rail congestion will effectively force more affected rail commuters to the automobile mode. The detailed impact on average travel time and generalised cost of car trips into the CBD under various levels of rail capacity constraint are reported next.

5.5.1 Generalised Cost of Automobile Trips into the CBD

Table 5.9 shows the average generalised cost of automobile trips into the CBD between 7-9am for each distance band under the Base Case and the various levels of rail capacity constraint. The Base Case represents the current (2006) status. The generalised cost of automobile trips shown in Table 5.9 essentially comprises travel time, vehicle operating costs and parking charges.

Table 5.9: MITM output – The average generalised cost of automobile trips for Base Case (2006) and various levels of rail capacity constraint

Distance from CBD (km)	Base Case	Rail Capacity Constraint (%)				
		10	20	30	40	50
0-9.9	$15.64	$15.91	$16.29	$16.78	$17.36	$18.04
10-19.9	$18.57	$18.87	$19.28	$19.81	$20.48	$21.32
20-29.9	$21.73	$22.25	$22.92	$23.74	$24.71	$25.83
30-39.9	$24.13	$24.59	$25.19	$25.92	$26.80	$27.85
40-49.9	$26.99	$27.39	$27.89	$28.49	$29.19	$30.00
≥ 50	$30.93	$31.36	$31.82	$32.32	$32.88	$33.53
Wt ave generalised cost per auto trip	$18.00	$18.86	$19.72	$20.62	$21.59	$22.66

As shown in Table 5.9, the average generalised cost of automobile trips into the CBD in the AM peak for those employees residing within 10km from the CBD in the base case is $15.64. The average cost is about 2 times higher at $30.93 for those that travel from 50km or further into the CBD. The weighted (based on traffic volume) average generalised cost per automobile trip into the CBD in the Base Case in the AM peak is about $18 (see last row of Table 5.9).

Under a 10% rail capacity constraint scenario, the AM peak average generalised cost of automobile trips into the CBD for those employees residing within 10km from the CBD is envisaged to increase by about 28 cents to $15.91. The absolute increase in generalised cost was highest for employees who live between 20 – 40km from the CBD; for example, for those that reside between 20-30km from the CBD, the increase is anticipated to be 52 cents while those that live between 30-40km from the CBD, their generalised cost was estimated to increase by about 46 cents.

This is due to the relatively higher percentage increase in traffic congestion in these areas when rail capacity is constrained – see Figure 5.7. The relatively higher increase in traffic congestion is not surprising given that the majority of the rail users going into the CBD come from these areas (see Figure 4.11). As the other PT modes in these areas are low (see Figure 4.15) and walking and cycling are not viable alternatives, car mode is the most attractive option for the affected rail users residing in these areas.

As the level of rail capacity constraint increases, the generalised cost of automobile trips (across the distance bands) were generally observed to rise by an increasingly (albeit slightly) larger magnitude. This is most evident in the increase in the weighted average generalised cost per CBD automobile trip – this increases by about 4.8% under a 10% rail capacity constraint scenario compared to the Base Case; however, under a 50% rail capacity scenario the weighted generalised cost per CBD automobile trip is estimated to increase by about 25.9% compared to Base Case.

It is noted that the rise in the generalised cost of automobile trips for every 10% increase in rail capacity constraint are not substantial. This is primarily because the volume of diverted "rail-to-car" trips is small compared to the total volume of automobile trips made throughout the entire highway network[20] - hence the new car trips will not result in a significant increase in the generalised cost. In addition, parking charges make up a significant proportion of the generalised cost of automobile trips entering the CBD[21]. This will dilute any effect of increase in the travel time and vehicle operating cost components on the overall generalised cost of automobile trips.

[20] According to DOT (2008c), about 1.5 million auto trips are made throughout the entire highway network in the AM peak in the Base Case. MITM's output suggests that every 10% increase in urban rail constraint would introduce about 2,000 new car trips (diverted from rail) into the highway network. This is about 0.13% of the total automobile trips.

[21] Parking charges make up about 50% - 80% of the total generalised cost of automobile trips into the CBD. For example, for automobile trips that originated from within 10km from the CBD, parking charges make up about $12 of the generalised cost; travel time and vehicle operating cost make up the other $3.64 (for Base Case). Any increase in travel time essentially only affects the latter portion of the generalised cost.

On average, the weighted generalised cost per CBD automobile trip is estimated to increase by about $0.93 for every 10% rail capacity constraint. This means for example, the generalised cost per CBD automobile trip is expected to increase from $18 (Base Case) to about $18.93 for a 10% rail capacity constraint and to $19.96 for a 20% rail capacity constraint on average. Based on the mode shares of PT and automobile CBD trips and the weighted average generalised cost per PT trip (of about $13.79) from MITM, this translates into an increase in the average generalised cost per CBD trip in the AM peak from $14.27 to $14.35 -$14.46. This represents an average increase of about $0.08 - $0.19[22]. The changes in the average generalised cost of CBD trips between the Base Case and various rail capacity scenarios have been used to estimate the agglomeration benefits and productivity shocks in Chapter Eight using the method adopted by the UK and New Zealand.

Table 5.10 shows the corresponding increase in the generalised cost as a percentage as compared to the Base Case. These changes in the generalised cost of CBD automobile trips have been used with auto trip elasticity values from secondary research to estimate the number of CBD automobile trips that may be potentially "priced out" of the highway network due to rising traffic congestion in Section 5.6.3. As observed from Table 5.10, the average generalised cost of automobile trips grew the fastest for the 20-40km distance band across all levels of rail capacity constraint. This suggests that when rail capacity is constrained, the greatest growth in traffic congestion is expected to occur in these areas.

Table 5.10: MITM output – The percentage increase in average generalised cost of automobile trips under various levels of rail capacity constraint compared to Base Case

Distance from CBD (km)	Rail Capacity Constraint (%)				
	10	20	30	40	50
0-9.9	1.76%	4.21%	7.31%	11.04%	15.40%
10-19.9	1.62%	3.85%	6.70%	10.31%	14.83%
20-29.9	2.37%	5.45%	9.23%	13.69%	18.85%
30-39.9	1.93%	4.41%	7.44%	11.09%	15.44%
40-49.9	1.46%	3.32%	5.54%	8.15%	11.16%
≥ 50	1.38%	2.86%	4.51%	6.31%	8.41%

[22] Please refer to Section 8.5, Table 8.13 for more details.

As explained earlier, the significant growth in highway traffic for these areas is possibly due to the lack of other PT alternatives for the affected commuters in these areas as suggested by Currie and Senbergs (2007). In addition, estimates from MITM suggest that the average trip length of the CBD-bound automobile trips originating from these areas is between 23-32km. This may be too challenging to consider cycling or walking as possible alternatives. Hence, the automobile mode is the only option available for these people in the absence of rail provision. The results suggest those automobile users residing within 30-40km away from the CBD are likely to be most affected by any rail capacity constraint followed by those who stay within the 20-30km from the CBD.

5.5.2 Average Travel Times of Automobile Trips into the CBD

Table 5.11 shows the average travel times of automobile trips into the CBD in the AM peak for each distance band for incremental 10% rail capacity constraints. This information has been used to illustrate possible increases in travel times under different rail congestion scenarios in the CBD employer survey (Chapter Six).

Table 5.11: MITM output – The average travel times of automobile trips for each level of rail capacity constraint (minutes)

Distance from CBD (km)	Base Case	Rail Capacity Constraint (%)				
		10	20	30	40	50
0 – 9.99	9.0	9.8	10.1	10.3	10.7	11.1
10 – 19.99	23.0	25.6	26.3	27.1	28.1	29.1
20 – 29.99	32.5	36.5	37.7	38.9	40.4	42.0
30 – 39.99	39.0	43.9	45.4	46.9	49.2	51.1
40 – 49.99	44.8	50.3	52.1	54.3	56.4	58.6
≥ 50	57.1	62.3	63.1	65.2	66.8	69.1
Weighted travel time (min)	18.3	20.5	21.3	22.5	23.7	25.0
Average increase in travel time (weighted) compared to Base Case	-	12.3%	17.2%	23.2%	29.3%	36.5%

As shown in Table 5.11, the average AM peak travel time of automobile trips into the CBD under a 10% rail capacity constraint is estimated to increase by 12.3% (weighted according to traffic volume from each distance band) compared to the Base Case. Output from MITM indicates that a subsequent increase in rail capacity constraint (and hence traffic congestion) results in increasingly higher average travel times of automobile trips into the CBD. This suggests that the highway network serving the CBD is getting increasingly congested as more rail commuters divert to car use due to rising rail congestion. On average, every 10% increase in rail capacity constraint raises the average auto travel time into the CBD by about 8%.

5.6 Assessment – Estimation of Potential Trip and Employment Suppression Impacts associated with a Rail Capacity Constraint

This section presents the assessment pertaining to the trip and employment suppression impact associated with a rail capacity constraint. The total amount of rail trips that may potentially be affected has been estimated based on the level of rail capacity constraint. The number of affected CBD rail commuters who may give up their work trip has been estimated using the probabilities shown in Figure 5.6.

On the other hand, trip elasticities with respect to generalised cost of travel (from secondary research) have been used with MITM's output to estimate the number of automobile trips that may potentially be affected when traffic conditions deteriorate. The number of work-related automobile trips that may be suppressed has also been estimated using the probabilities shown in Figure 5.6.

This section first presents the secondary research carried out on trip elasticities. This is followed by the estimation of the trip and employment impact associated with a rail capacity constraint.

5.6.1 Secondary Research – Evidence from Trip Elasticity Studies

Transport demand elasticity is the ratio of the proportionate change in travel demand to the proportionate change in any factor which causes that change in the demand (Booz Allen Hamilton, 2003). Booz Allen Hamilton (2003) highlights that elasticities offer a practical method to predict the response of travel demand to a change in one of the demand drivers.

The evidence from public transport demand elasticity studies (for example Litman, 2008b, TRB, 2004, Booz Allen Hamilton, 2003, Cervero, 1990) gives a consistent indication that long run (LR) effects are generally about twice that of short run (SR) effects and that captive riders[23] (especially workers) have much lower propensity than choice riders to shift into the off-peak period. It would therefore be reasonable to expect the trip suppression impact associated with urban rail constraint in the LR to be twice the SR[24] impacts.

In terms of the evidence on the elasticity of automobile travel demand with respect to the total generalised cost of the car trip, Booz Allen Hamilton (2003) point out that there is only limited evidence from international literature and "they were not able to identify any Australian or New Zealand generalised cost estimates" (Appendix K, page K-1). In consideration of the transferability of such estimates from New Zealand to Australia context, this research adopted Booz Allen Hamiltons' (2003) recommended SR value of -0.6 (on marginal generalised costs[25]) and a LR value of -1.0 for New Zealand.

[23] See Section 5.3.1 for TRB's (2004) definition of captive and choice riders.

[24] Booz Allen Hamilton (2003) defines short-run as a typical period of about 12 months while long-run as more than 8 years or a typical period of 10-12 years. This timescale definition is consistent with that assumed in CGE modelling – Horridge (2003, page 58) suggests that in Computable General Equilibrium modelling, a short term is considered to be 1-3 years and a long-run is a period longer than that.

[25] Booz Allen Hamilton (2003) defined marginal generalised costs to comprise essentially vehicle operating costs and travel time and exclude car purchase, fixed costs and arguably maintenance. This is consistent with the generalised costs generated by MITM for this research.

5.6.2 Rail Trip Suppression Impact

The total number of work-related rail trips that could potentially be suppressed in the short run under various levels of rail capacity constraint in the AM peak has been estimated using the methodology outlined below.

5.6.2.1 Methodology

Step 1: Estimation of amount of work-related rail trips affected

The potential range of CBD employees that may be "forced-out" of the train system under various levels of constraint in rail capacity was estimated as follows:

- The upper limit was estimated based on the total AM peak rail capacity provision (i.e. 138,000 passenger trips) serving Melbourne CBD; VATS data (TRC,1999) indicated that 83% of the AM peak hour trips are work–related
- The lower limit was estimated based on the AM peak work-related rail demand of 72,200 trips (as estimated in Section 4.3.2).

Step 2: Estimation of the amount of work-related rail trips cancelled

The number of work-related rail trips that may potentially be suppressed under various levels of rail congestion were estimated using the probabilities shown in Figure 5.6.

For example, under a SR 10% rail capacity constraint, about 7,220 – 11,450 rail trips could be affected. The lower limit of 7,220 rail trips is estimated by taking 10% of the AM peak work-related rail demand of 72,200 trips (i.e. 10%*72,200). The upper limit of 11,450 rail trips is estimated by taking 10% of the rail capacity provided to serve work-related trips (i.e. 10%*83%*138,000). According to Figure 5.6, 18.5% of the affected rail commuters may cancel their trip. Applying this 18.5% factor to the 7,220 – 11,450 range, it is estimated that 1,336 – 2,120 rail trips may be cancelled under a 10% rail capacity constraint in the SR.

The LR effects are estimated to be twice the magnitude of the SR impacts based on evidence from elasticity studies.

5.6.2.2 Results

Table 5.12 presents the estimated number of AM peak work-related rail trips that could potentially be suppressed in the SR and LR. The results indicate that a 10% constraint in rail capacity can cause a SR suppression of 1,336 - 2,120 work-related rail trips. In the LR, this effect can potentially escalate to the cancellation of 2,671 - 4,240 rail trips.

Table 5.12: Estimated number of AM work-related rail trips that may be cancelled for various levels of rail capacity constraint (passenger trips)

Estimated number of work-related rail trips suppressed (passenger trips)	Rail Capacity Constraint (%)				
	10	20	30	40	50
Low er Limit (SR)	1,336	2,671	4,007	5,343	6,679
Upper Limit (SR)	2,120	4,240	6,359	8,479	10,599
Low er Limit (LR)	2,671	5,343	8,014	10,686	13,357
Upper Limit (SR)	4,240	8,479	12,719	16,959	21,198

Note: SR – Short run; LR – Long run

5.6.3 Automobile Trip Suppression Impact

The total number of automobile trips that could potentially be cancelled under various levels of rail capacity constraint in the AM peak was estimated based on the approach outlined below.

5.6.3.1 Methodology

Step 1: Estimation of the number of work-related automobile trips affected

The total number of CBD automobile trips (for each distance band) that may be potentially "priced out" of the highway network due to rising traffic congestion (and hence make alternative choices) was estimated as follows.

- The percentage change in the average generalised cost of automobile trips from MITM (Table 5.10).
- The trip elasticity values recommended by Booz Allen Hamilton's (2003) – i.e. SR value of -0.6 and LR value of -1.0.

The proportion of affected automobile trips that is related to work purposes was estimated using information from VATS data – VATS data (TRC, 1999) indicated that 83% of the AM peak hour trips are work – related.

Step 2: Estimation of the number of work-related automobile trips cancelled

Of the affected work-related automobile trips estimated above, the proportion that may potentially be cancelled under various level of rail congestion were estimated using the probabilities shown in Table 5.8.

In other words, the total number of work-related auto trips cancelled for each level of rail capacity constraint in the SR and LR is

$$= \sum_{db=0-0.99km}^{\geq 50km} (\%gc * \Omega * 83\% * P^{CT}) \qquad \text{(Equation 5.11)}$$

where

- db stands for distance band (as shown in Table 5.10)
- *%gc* is the percentage change in the average generalised cost of automobile trips for each distance band compared to Base Case (as shown in Table 5.10)
- Ω is the respective trip elasticity
- P^{CT} is the probability to cancel auto trip as shown in Table 5.8.

5.6.3.2 Results

The total number of AM peak work-related automobile trips that may be suppressed under various levels of rail capacity constraint in the short and long term are shown in Table 5.13.

Table 5.13: Estimated volume of AM peak work-related automobile trips that may be cancelled for various levels of rail capacity constraint (automobile trips)

Estimated number of car trips cancelled (car trips)	Rail Capacity Constraint (%)				
	10	20	30	40	50
Short Term	49	133	257	435	662
Long Term	82	222	429	718	1,104

The assessment indicates that in the SR, a 10% constraint in rail capacity is associated with the suppression of about 49 work-related automobile trips. The results suggest that as the rail capacity constraint level increases, the number of work-related automobile trips that may potentially be suppressed also rises but at a faster pace. This is a manifestation of the higher rate of increase in the generalised costs as the rail congestion level rises.

The LR impact follows the same trend as the SR impacts but the magnitude of the number of car trips suppressed is observed to be about 1.5 – 2 times higher.

5.6.4 Resultant Impact to Melbourne CBD's Employment

The volume of work-related rail trips that may be potentially suppressed as shown in Table 5.12 is assumed to be the number of CBD employee trips that may be cancelled in times of rail capacity constraint. However, in the context of automobile trips, it is necessary to convert the volume of automobile trips into persons trips.

According to information from DOT (2008c) and VATS data (TRC, 1999), this research estimated that the weighted average car occupancy for work-related automobile trips into Melbourne CBD in the AM peak is about 1.147 i.e. each automobile that enters the CBD carries on average 1.147 passengers. This factor was applied on the volume of automobile trips that may be cancelled in the short and long term as shown in Table 5.13 to estimate the corresponding employment suppression impact. The results are presented in Table 5.14.

Table 5.14: The estimated CBD employment suppression impact due to cancellation of automobile trips (number of employees)

Estimated number of persons trips cancelled (person trips)	Rail Capacity Constraint (%)				
	10	20	30	40	50
Short Term	57	153	295	499	760
Long Term	94	254	492	823	1,266

It is estimated that about 57 CBD auto commuters would give up their employment under a 10% rail capacity constraint scenario in the short term. In the long term, this number is envisaged to escalate to 94 employees. As shown in Table 5.14, the number of CBD employees who drive to work is anticipated to fall at a higher rate as the level of rail congestion increases steadily from 10% to 50%.

The total CBD employment suppression impact associated with AM peak urban rail capacity constraint was then estimated by the summation of the total number of affected rail and auto users who are likely to suppress their work trips – i.e. the summation of Table 5.12 and 5.14. The results are presented in Table 5.15 and 5.16. Table 5.15 shows the absolute number of employees that may give up their CBD employment while Table 5.16 presents the employment suppression impacts as a percentage of the CBD's total employment.

Table 5.15: Total amount of employment estimated to be suppressed for various levels of rail capacity constraint – short and long term effects

Estimated volume of CBD employment suppressed (no. of workers)	Rail Capacity Constraint (%)				
	10	20	30	40	50
Low er Limit (SR)	1,392	2,824	4,302	5,842	7,438
Upper Limit (SR)	2,176	4,392	6,655	8,978	11,359
Low er Limit (LR)	2,766	5,597	8,506	11,509	14,623
Upper Limit (SR)	4,334	8,734	13,211	17,782	22,464

Table 5.16: Share of employment estimated to be suppressed for various levels of rail capacity constraint – short and long term effects

Estimated percentage of CBD employment suppressed	Rail Capacity Constraint (%)					Ave suppression per 10% rail onstraint
	10	20	30	40	50	
Low er Limit (SR)	0.67%	1.35%	2.06%	2.80%	3.57%	0.69%
Upper Limit (SR)	1.04%	2.11%	3.19%	4.31%	5.45%	1.07%
Low er Limit (LR)	1.18%	2.39%	3.64%	4.92%	6.25%	1.21%
Upper Limit (SR)	1.85%	3.73%	5.65%	7.60%	9.60%	1.88%

Table 5.15 suggests that on average, a 10% constraint in rail capacity may be associated with a short term CBD labour supply impact of about 1,392 - 2,176 jobs. It was estimated in Section 4.2.2 that the total employment for Melbourne CBD will reach 208,500 in the short term. Based on this short term CBD employment projection, the potential 1,392 – 2,176 job lost represents an employment impact of about 0.67% - 1.04%. As highlighted earlier, as the rail congestion level increases, the employment suppression impacts also rise but at a higher rate. This is evident from Table 5.16. For example, the employment suppression impact for a 20% constraint is about 1.35% - 2.11% which is slightly more than twice the impact associated with a 10% rail capacity constraint. On average, every additional 10% rail capacity constraint is estimated to suppress 0.69% - 1.07% of the CBD employment in the short term.

In the long term, a 10% rail capacity constraint may potentially discourage on average some 2,766 – 4,334 employees from working in the CBD. As highlighted in Section 4.2.2, total Melbourne CBD employment is forecast to grow to 234,000[26] by 2016 (SGS Economics and Planning Pty Ltd, 2008). Based on this, the 10% rail capacity constraint is associated with a long term employment impact of about 1.18% - 1.85%. Again, the employment suppression impacts are expected to increase at a higher rate as the level of rail capacity constraint increases. On average, every additional 10% rail capacity constraint is estimated to suppress 1.21% - 1.88% of the CBD employment in the long term.

5.6.5 Interpretation of MITM Output

Section 4.2 benchmarked the current and future positions of the overall capacity of the train network serving Melbourne CBD in the AM peak so that this research is able to interpret how the traffic congestion status derived using MITM fits into the real world.

As indicated previously, the Base Case in MITM represents the 2006 traffic situation in Melbourne (DOT, 2008d). Figure 4.16 shows that in 2006, the AM peak rail demand exceeds the capacity provision by about 16% and today (2009), rail capacity constraint is about 31.5%[27]. This means that MITM's output for a 15% rail capacity constraint scenario essentially represents the highway congestion effects that have taken place over the last few years. Based on the employment suppression impacts estimated earlier, the results suggest that Melbourne CBD could have grown by an additional 1.04% - 1.61% if the rail capacity provision serving it has been adequate, paribus ceteris. This represents a lost of potentially some 2,100 – 3,200 jobs that could otherwise have been supported in the CBD.

[26] This 2016 employment growth projection for the CBD is considered reasonable as SGS (2008) indicated that the availability of transport infrastructure provision was considered in their study – this suggests that they may have already considered the potential impact of rail capacity constraint on growth projections. In addition, the benchmarking exercise presented in Section 4.2 also suggests that the Government's rail plan for the next 5 years is able to contain the rail congestion situation up to 2015. This supports the earlier proposition that the SGS projection is considered reasonable.

[27] The rail benchmarking assessment was carried out in early 2009; hence the FY 2008 – 2009 figure shown in Figure 4.16 was adopted in this analysis to represent the current status.

In the SR, Figure 4.16 suggests that the AM peak rail demand is anticipated to exceed the capacity provision by about 40%; this is about 10% higher than the current (2009) status. This means that MITM's output for the 10% rail capacity constraint scenario (i.e. the difference between 40% and 30% rail capacity constraint scenarios) essentially represents the short term highway congestion effects.

The Victorian Transportation Plan (DOT, 2009b) also indicates that there is a longer term intention (beyond 2012) to further expand the urban rail fleet size and to invest in urban rail infrastructure. This intention, together with the rail congestion status beyond 2010 as shown in Figure 4.16, suggests that the rail congestion status for within the 10 to 12 years is not envisaged to worsen beyond 10% as compared to current (2009) status. This means that MITM's output for the 10% rail capacity constraint scenario may also represents the long term highway congestion effects.

The above assessment suggests that the agglomeration diseconomies associated with a 10% rail capacity constraint is a reasonable basis of assessment and presentation for the subsequent chapters. This is adopted in this research in particular for the comparative assessment of agglomeration results (Chapter 10).

5.7 Summary

This chapter presents the transport modelling research that has been carried out with MITM. MITM has been used in this research to simulate an array of transport scenarios to illustrate how the current (2006) highway travel times into Melbourne CBD during the AM peak is likely to be affected by various degrees of rail accessibility constraint. The output from MITM has been used to estimate the employment suppression and productivity impact to Melbourne CBD associated with an urban rail capacity constraint. In addition, MITM's output has also been employed to specify possible increases in travel times under different rail congestion levels, so that employers can better understand the potential impact of rail congestion on their businesses, in the employer survey.

As part of the modelling process, secondary research was conducted to investigate how CBD employees are likely to change their travel behaviour in circumstances of rail capacity constraint. Relevant information was found primarily in the work of HLB (2003). Based on their findings, it was estimated that of the rail users affected by the rising rail congestion, 18.5% are likely to give up their employment in the CBD while 30% are likely to shift to automobile use under circumstances of rail capacity constraint. The latter is envisaged to increase the congestion level on the highway network which will affect the CBD auto commuters; of those affected auto commuters, 33.3% are envisaged to give up their work trip to the CBD.

The increase in highway traffic due to a rail capacity constraint was modelled in MITM by adding the diverted rail-to-car trips to the base case highway demand matrix and then performing a Highway Assignment run with the expanded highway demand matrix. MITM's output was used with trip elasticities to estimate the number of CBD automobile trips that may potentially be affected when traffic conditions deteriorate. On the other hand, the amount of rail trips affected was estimated based on rail demand and capacity provided to serve the CBD.

MITM's output suggests that on average the AM peak travel time of automobile trips into the CBD under every additional 10% rail capacity constraint is estimated to increase by 8.8% on average. This translates to an average increase in about $0.11 - $0.22 in the average generalised cost per trip (for all trips) into the CBD in the AM peak. The changes in the average generalised cost of CBD trips between the Base Case and various rail capacity scenarios have been used to estimate the productivity shocks and agglomeration benefits in Chapter 8 and 9 respectively, using the approach adopted by the UK and New Zealand

Based on a benchmarking of the overall AM train capacity serving Melbourne CBD, it is concluded that MITM's output for the 10% rail capacity constraint scenario essentially represents the highway congestion effects for both the short and long term. Using MITM's output, it was estimated that a 10% rail capacity constraint was associated with an average short term labour supply suppression of about 0.69% - 1.07% of the CBD employment. In the long term, this impact is expected to increase to 1.21% - 1.88% on average. These employment suppression estimates are subsequently compared against the findings from the CBD employer survey (Chapter 6), which also serves as cross check for the impacts estimated based on MITM's output.

CHAPTER 6

Melbourne CBD Employer Survey

6.1 Introduction

This chapter presents the key findings from the Melbourne Central Business District (CBD) employer survey. This survey was conducted to gather feedback from CBD employers on how rising rail congestion may affect their remuneration and employment plans. This primary survey represents another approach[1] used by this research to explore how CBD employment might change as a result of changes in transport and travel. The potential employment suppression impacts estimated based on this primary data collection method are also reported in this chapter. Figure 6.1 shows how this employer survey (shown boxed in red) fits into the overall framework of this research methodology.

This chapter is structured in the following sequence.

- **Section 6.2 -** **Survey Approach** outlines how the survey exercise has been conducted.
- **Section 6.3 -** **Analysis of Survey Results** presents the survey findings.
- **Section 6.4 -** **Key Observations and Feedback** highlights the key observations and feedback from the survey.
- **Section 6.5 -** **Summary** concludes this chapter.

[1] As mentioned in the research methodology (Chapter 3), this research measures the agglomeration effects in urban rail using 2 measures. The potential employment suppression impact is one of the measures. This primary survey is the 2nd of 3 approaches explored in this research to estimate the potential employment suppression impact associated with an urban rail capacity constraint.

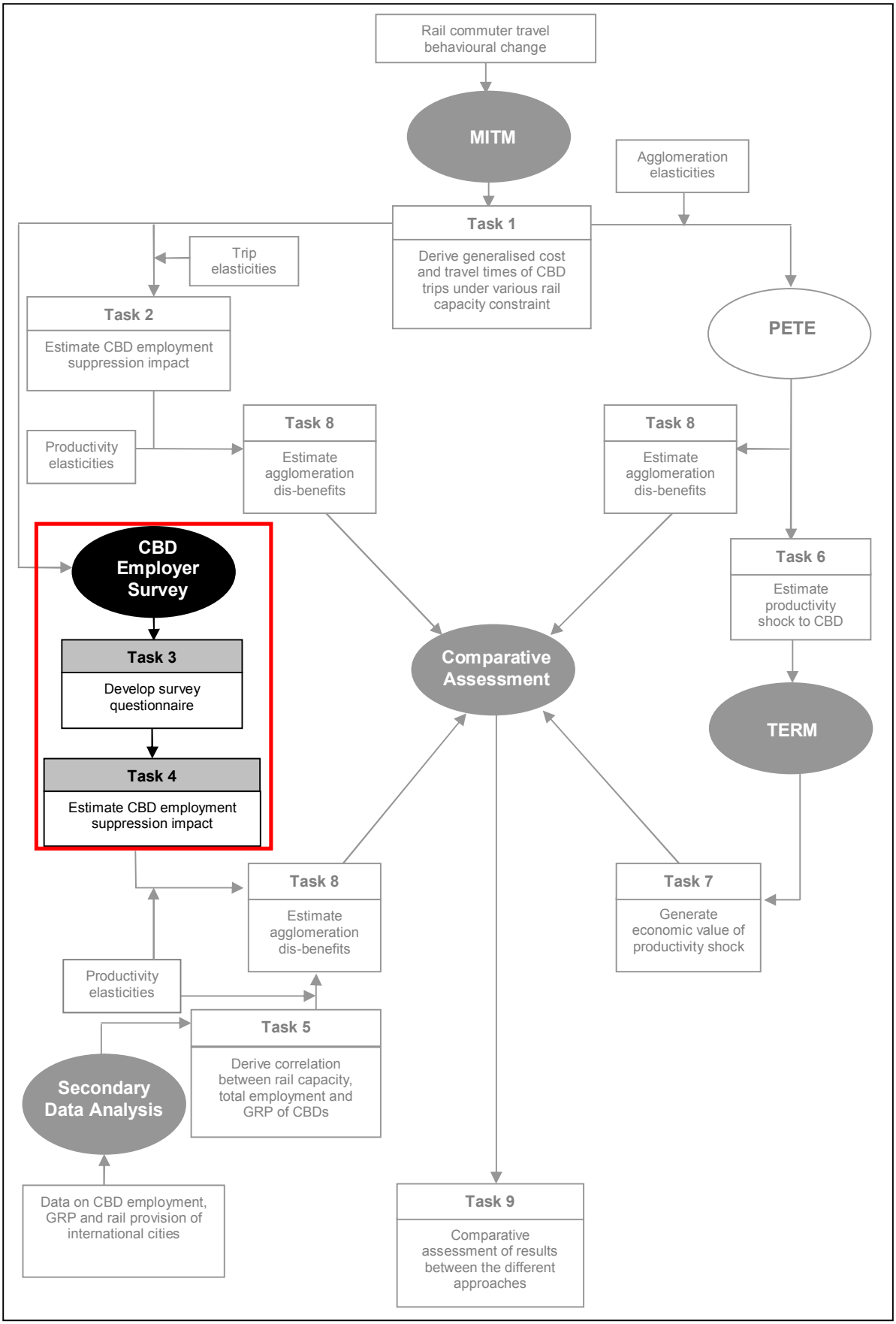


Figure 6.1: Research focus of Chapter Six

6.2 Survey Approach

Overall, this stage of research comprises six steps as shown in Figure 6.2.

1. Literature review
2. Sample size and survey questionnaire development
3. Ethics clearance
4. Pilot survey
5. Survey execution and monitoring
6. Result analysis and documentation.

A field report which details these six steps is provided in Appendix C of this thesis. A full set of the survey questions is also provided in the field report. A summary of the survey approach is outlined in this chapter.

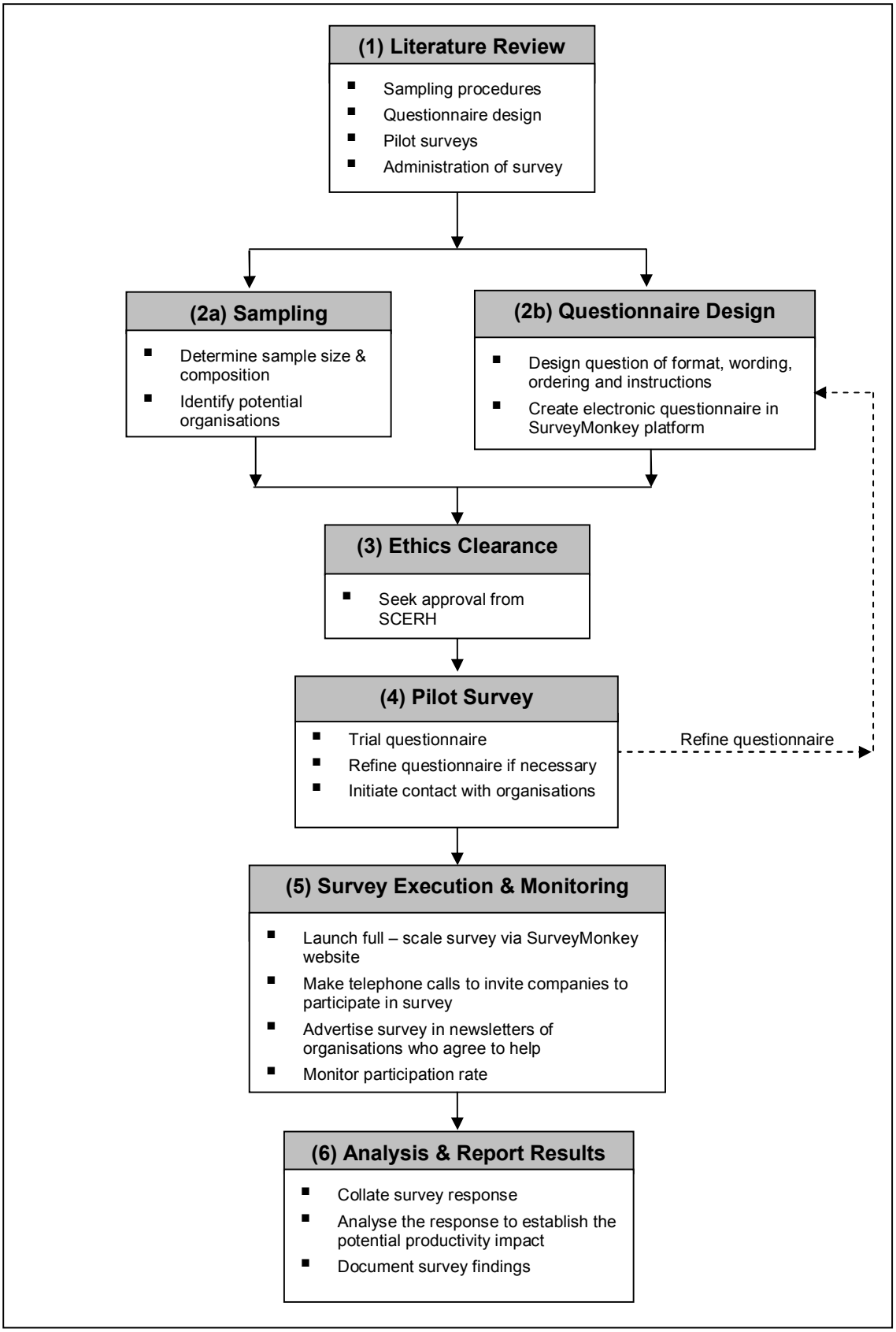


Figure 6.2: Melbourne CBD employer survey methodology

6.2.1 Questionnaire Design

The survey questionnaire comprises 18 questions which were designed to gather inputs on the following three aspects of the CBD businesses.

1. Details of firm (such as the industry the business belongs to) and employees (such as staff strength and mode of transport to work).
2. Firm's 'willingness-to-pay' (via increased remuneration) for various degrees of traffic congestion.
3. Impact of traffic congestion on future employment plans in the short term and their decision to continue to stay or leave the CBD should the traffic congestion worsen in the longer term.

The length of the questionnaire was designed so that the survey can be completed comfortably within 10-15 minutes. This was based on the work of Stopher (as cited in Richardson et al. (1995)) which indicates that a respondent's attention span during survey drops rapidly after 10-15 minutes.

The questions were arranged to guide the participants to first consider the profile of their employees and how their employees travel to work. This is to set the stage to seek the participant's view on how a rail capacity constraint might impact their businesses.

Output from the earlier MITM traffic scenario testing has been used to illustrate two hypothetical journey times to work in the CBD under 10% and 30% rail capacity constraint (termed as Scenario A and B in the survey respectively) to the participants. The hypothetical traffic information was presented in the survey to help the participants better appreciate the impact of rail constraint on work trip travel times. This is to assist respondents to estimate the potential implication of the increased travel times on their business costs and location decisions.

It was estimated in Chapter Five that a 10% rail capacity constraint (i.e. Scenario A) may potentially increase the average AM peak hour travel times of automobile trips into Melbourne CBD by 12.3% - see Table 5.11. However, for the purpose of the survey questionnaire, the figure was rounded to 15% to make it easier for the participants to estimate the potential increase in their automobile travel time. Similarly for Scenario B, the travel time increase of 23.2% (see Table 5.11) was rounded up to 25%.

6.2.2 Pilot and Main Survey

In compliance with the ethical requirements of the Monash University Standing Committee on Ethics Research Involving Humans (SCERH), ethical approval for the survey was sought prior to the pilot survey. SCERH's approval was granted on 14th May 2009 (approval number 2009000622). Thereafter, the pilot survey was conducted between 25thMay and 26th Jun 2009. The main survey commenced on 10th August 2009 and was completed on 30th September 2009.

The pilot survey involved 12 participants including eight academics and consultants with experience in planning and execution of surveys as well as four existing CBD employers. The pilot survey tested the opt-in process, clarity of questionnaire and user-friendliness of the electronic questionnaire in the SurveyMonkey[2] website. After reviewing the feedback gathered from the pilot survey, minor changes to the survey opt-in process and questionnaire were implemented for the main survey.

The main survey was conducted using the following steps.

1. The CBD companies were invited via telephone calls to participate in the survey. The company listing and telephone numbers were taken from Telstra's (2009) Australian Yellow Pages which is a business telephone directory.
2. The invitation was directed to the Human Resource Managers or any individual in a similar capacity who has knowledge of how the firm's remuneration packages or employment plans are likely to change in the near future.
3. A follow up email that contained the explanatory statement of the project and the web-link to the survey in the SurveyMonkey website was sent to the companies that expressed interest in participating.
4. Survey responses were collected via the SurveyMonkey platform.
5. The response rate was monitored daily so that any industry that falls short in terms of desired participation rate would be targeted again.

[2] SurveyMonkey is an on-line survey tool.

6.3 Analysis of Survey Results

About 600 telephone calls were made and 250 emails were sent during the main survey. In addition, the survey was advertised in the GoingSolar's "Sustainable Cities and Transport" Newsletter[3] between 8th to 23rd September 2009.

A total of 65 companies participated in the survey. Based on the number of telephone calls made, the result yielded a final opt-in rate to the survey of about 11%. The 65 companies employ a total of 1,110 employees which translated to a sample size of about 0.6% of the total CBD employment. While this sample size is smaller than the desired 1% of CBD employees (as indicated in the field report), the distribution of participants provides an even coverage of the various industry types as well as size of company[4]. This suggests that the achieved sample is acceptable though not perfect. The key results of the survey are also summarised in Table 6.1.

The analysis of the survey results are presented in the following sequence.

- **Section 6.3.1 -** **Remuneration impacts** presents the potential increase in remuneration to compensate for the increasing difficulty to access the CBD.
- **Section 6.3.2 -** **Short term employment impacts** presents the potential impact on employment plans of CBD firms for the next 1-2 years as traffic congestion increases.
- **Section 6.3.3 -** **Longer term employment impacts** presents the possible relocation of firms out of CBD in the longer term when congestion deteriorates further.
- **Section 6.3.4 -** **Accuracy of survey findings** presents the benchmarking of the survey sample and findings to ascertain the reasonableness of the survey findings.

The subsequent analysis of the survey results will be presented with the CBD firms divided into seven broad categories (as shown in Table 6.1) as per the questionnaire. This is consistent with the classification presented earlier in Section 4.2.1. The underlying rationale and principles of how these seven broad industrial categories were derived are explained in the field survey report (Appendix C).

[3] GoingSolar is a non-profit organisation with a popular circulation including CBD businesses.

[4] See Section 6.3.4 for a full discussion of the accuracy of the survey findings.

Table 6.1: Summary of key survey results

Industry	Finance & Insurance Services	Business Management Services	Food & Hotel Services	Wholesale & Retail Services	Public Administration, Healthcare & Social, Education & Training Services	Information Technology Services	Recreational, Rental & Hiring Services	Total / Weighted average
Total number of firms that participated in survey	11	17	6	6	9	11	5	**65**
Total employment of firms that participated in survey (no. of workers)	290	309	72	93	183	92	71	**1,110**
Remuneration Impact								
Potential increase in remuneration associated with Scenario A impact	1.95%	1.20%	3.49%	2.63%	1.31%	2.61%	5.72%	**2.09%**
Potential increase in remuneration associated with Scenario B Impact	3.27%	2.56%	6.47%	5.45%	2.27%	4.20%	9.08%	**3.75%**
Short Term Employment Impact								
Potential reduction in employment associated with Scenario A impact	0.69%	0.69%	1.81%	2.04%	0.74%	1.29%	1.42%	**0.97%**
Potential reduction in employment associated with Scenario B Impact	1.52%	1.46%	3.63%	3.12%	1.38%	2.45%	2.32%	**1.86%**
Long Term Employment Impact								
Total employment of firms that indicated a possible relocation out of the CBD in the long term	9	10	8	5	81	6	0	**119 (10.7%)**

Note:

- **Scenario A impact corresponds with a 10% rail capacity constraint**
- **Scenario B impact corresponds with a 30% rail capacity constraint**

6.3.1 Remuneration Impacts

The survey responses indicated that about 52% of the surveyed firms (weighted based on total employment)[5] are willing to consider increasing their remuneration packages to retain or attract new staff when rail congestion rises. Figure 6.3 shows the percentage of respondent firms (based on total employment of all surveyed firms) in each sector that have indicated that they are willing to increase their remuneration package to attract or retain staff when accessibility into the CBD during the AM peak becomes more difficult.

The responses suggest that firms in the Food and Hotel, Wholesale and Retail as well as the Recreational, Rental and Hiring sectors are more willing to increase their remuneration package to retain or attract new staff while those in the Public Administration, Healthcare and Education services and the Business Management services sectors are less willing. There was, however, no observable correlation between the size of the firm and their willingness to increase remuneration to retain or attract new staff.

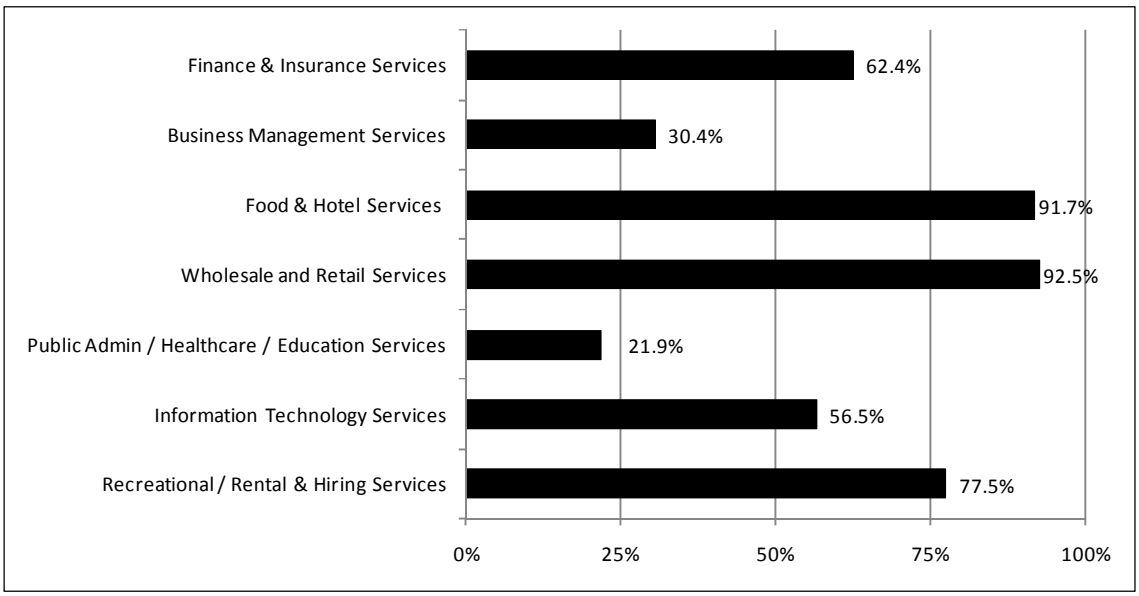
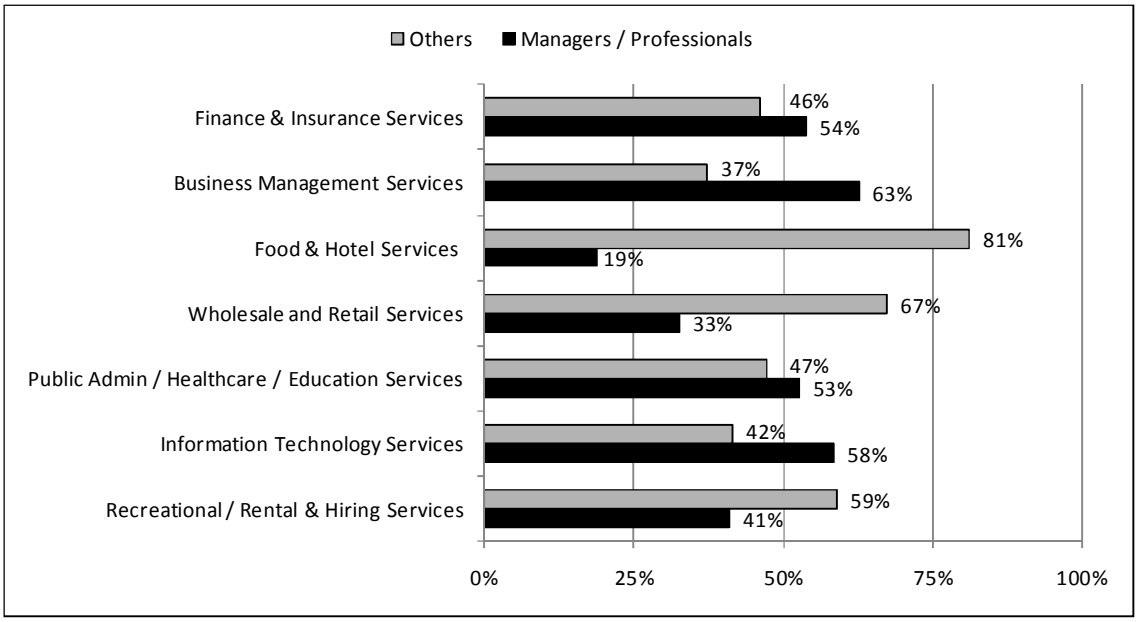


Figure 6.3: Percentage of companies (based on total employment) in each sector who are prepared to increase remuneration to attract or retain staff

[5] This weighted average was estimated by dividing the total employment of those firms that were willing to raise their remuneration with the total employment of all the firms that participated in the survey (i.e. 1,100 employees). This research views that the weighted average figure based on employment would provide a better indication of the actual proportion of firms that are willing to consider a wage raise as compared to the actual firm numbers.

Outcomes of Figure 6.3 may arise from the high share of non professional employees in the Food and Hotel, Wholesale and Retail as well as the Recreational, Rental and Hiring sectors – see Figure 6.4.



Source: Based on ABS (2006b)

Figure 6.4: Composition of occupation types for various sectors within the CBD

Information from ABS (2006i) suggests that these non - management / non – professional employees working in the CBD are drawing an average weekly income of about $825 which is about half the weekly income of the CBD Professionals and Managers. An increase in the cost of commuting to the CBD would represent a more significant reduction in the disposable income of this group. In addition, given that their skill set is not highly specialised, these workers are able to find similar jobs outside the CBD. Hence, employers in these sectors may be more willing to increase their remuneration to retain or attract new staff. On the flip side, their less specialised skill may also mean that they are more vulnerable when employers decide to reduce their labour demand.

Employees in the Business Management services sector are largely professionals. ABS's (2006i) data suggest that the professionals working in the CBD are drawing an average weekly income of about $1,430. Some of these professional firms have provided feedback (during the telephone call invitation to participate in the survey) that the demand for the skill sets and expertise of their employees are largely in the CBD. The demand for their expertise and the comparatively higher wages means that these professional employees would still work in the CBD regardless of the congestion level. This may explain the lower inertia for the employers in these sectors to consider increasing their remuneration to retain or attract new staff when congestion level rises.

The Public Administration sector has also indicated that their operational costs are largely governed by State Government funding. Hence they do not have a direct capacity to increase remuneration when commuting costs rise.

A similar pattern is observed when the amount of increment in remuneration that the various sectors are willing to pay is examined – see Figure 6.5. The survey responses suggest that not only are the Food and Hotel, Wholesale and Retail and the Recreational, Rental and Hiring sectors more willing to increase their remuneration to retain or attract new staff, they are also willing to increase it by a larger percentage compared to those firms in the Public Administration, Healthcare and Education services and the Business Management services sectors.

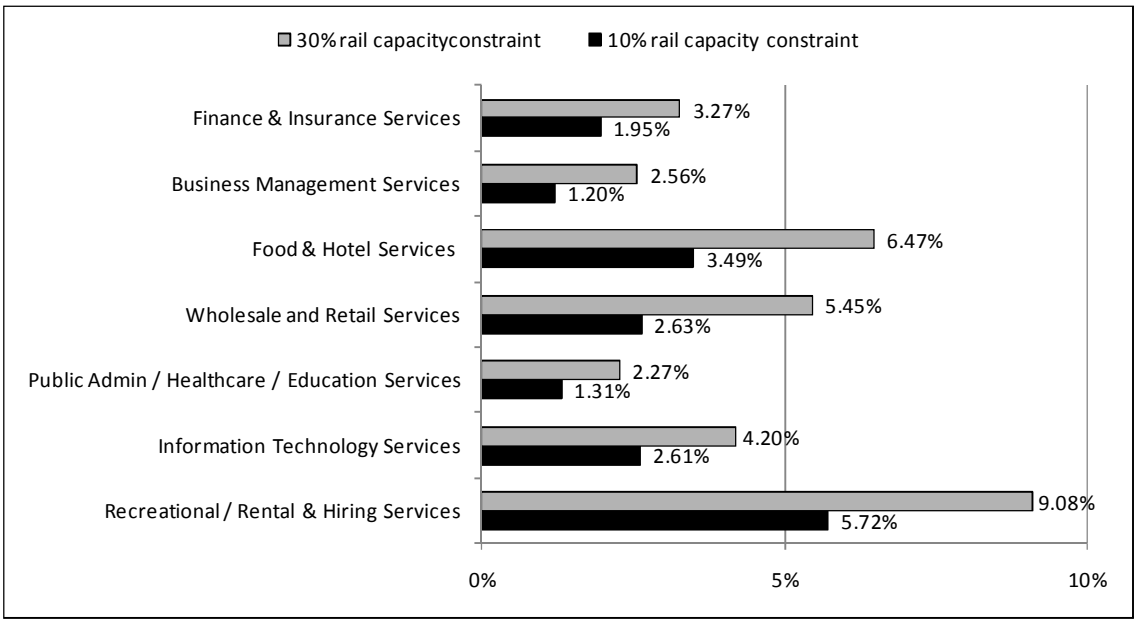


Figure 6.5: Percentage increase in annual remuneration that each sector is willing to pay for 10% and 30% rail capacity constraint

The higher 'willingness-to-pay' of the first group of industries could be due to the generally lower wages that the employees in these sectors are currently being paid (since the majority of their workforce is comprised of lower income earners such as technicians and sales workers) compared to those professionals working in the Finance and Insurance services as well as the Business Management services.

As shown in Figure 6.5, the Recreational, Rental and Hiring services sectors are willing to increase their annual remuneration by the largest magnitude while the annual remuneration increment indicated by the Public Administration, Healthcare and Education services are the lowest. The larger magnitude of remuneration compensation indicated by the Recreational, Rental and Hiring sectors may be due to the comparatively lower base salaries or higher mobility of the workers in these industries. On the other hand, the funding constraint of the Public Administration, Healthcare and Education sector which made up the largest proportion of this group may explain why this group of industries are only willing to increase annual remuneration by the smallest margin when commuting cost increases.

Overall, the survey results suggest that CBD employers are willing to increase annual remuneration by a weighted-average of about 2.09%[6] ± 0.15% (at 95% confidence interval) under traffic congestion associated with 10% rail capacity constraint. At the higher congestion level associated with 30% rail capacity constraint, the survey results suggest that CBD employers are willing to raise annual remuneration on average (weighted) by about 3.76%[5] ± 0.25% (at 95% confidence interval).

It is observed that the annual remuneration impact of the 30% rail capacity constraint scenario is about twice the magnitude of the 10% rail capacity constraint scenario. This corresponds with the hypothetical traffic scenarios which indicate that the 10% and 30% rail capacity constraint would increase the average AM peak automobile travel times into the CBD by about 15% and 25% respectively (i.e. almost double the effect). The survey responses suggest that CBD employers were only considering the associated increase in automobile travel time rather than the level of rail capacity constraint when answering the questionnaire.

[6] The annual remuneration impact of 2.09% and 3.76% are weighted averages based on the employment of the surveyed companies. If the results were weighted using employment data from the Census of Land Use and Employment (CLUE) (City of Melbourne, 2006), the corresponding annual remuneration impact is 2.12% and 3.81% which are not significantly different.

6.3.2 Short Term Employment Impacts

The short term is defined in the survey questionnaire as the time period from 2009 to 2011 i.e. the next 1-2 years[7]. About 27% of the surveyed companies (based on total employment of all surveyed firms)[8] have indicated that rising traffic congestion may have some impact on their short term employment plans.

Figure 6.6 shows the percentage of firms (based on total employment of all surveyed firms in each sector) that have indicated that the rising traffic congestion may have a detrimental impact on their short term employment plans.

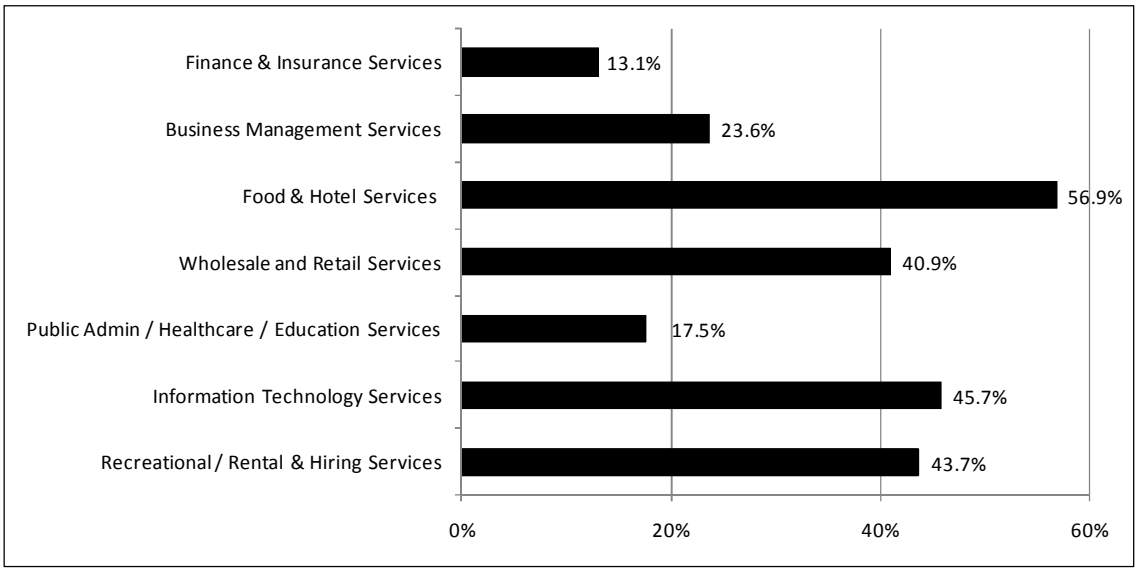


Figure 6.6: Percentage of companies (based on total employment) in each sector which indicate that rising congestion may have a detrimental impact on their short term (1-2 years) employment plans

[7] This is to be consistent with the timescale assumption adopted in trip elasticities used in Chapter 5 and the Computable General Equilibrium modelling reported in Chapter 8.

[8] This weighted average was estimated by dividing the total employment of those firms that indicated the rising traffic congestion may affect their short term labour demand with the total employment of all the firms that participated in the survey (i.e. 1,100 employees). This weighted average figure based on employment would provide a better indication of the actual proportion of firms that consider the rising traffic congestion to have an impact on their short term labour demand.

The responses suggest that the employment plans of firms in the Food and Hotel, Wholesale and Retail as well as the Recreational, Rental and Hiring sectors are more likely to be affected by the increasing traffic congestion while those in the Public Administration, Healthcare and Education services, Finance and Insurance services and the Business Management services sectors may suffer a smaller employment impact in the next 1-2 years.

The survey returns reinforce the earlier suggestion that industries where the majority of their workforce are non-professionals are more likely to be affected should CBD traffic condition deteriorate. On the other hand, sectors such as the Finance and Insurance services and Business Management services sector where the employees are largely professionals are more immune to the detrimental effects of rail congestion on their future employment plans in the short term. This is because their employees are more captive to jobs in the CBD to a bigger extent.

A similar trend is observed when one examines the overall magnitude of employment impact – see Figure 6.7. The potential employment plans of the Food and Hotel, Wholesale and Retail and the Recreational, Rental and Hiring sectors are more susceptible to higher traffic congestion compared to the Public Administration, Healthcare and Education services and the Business Management as well as Finance and Insurance sectors. Again, this is likely to be due to the comparatively lower employment mobility of the workers in the latter group of sectors.

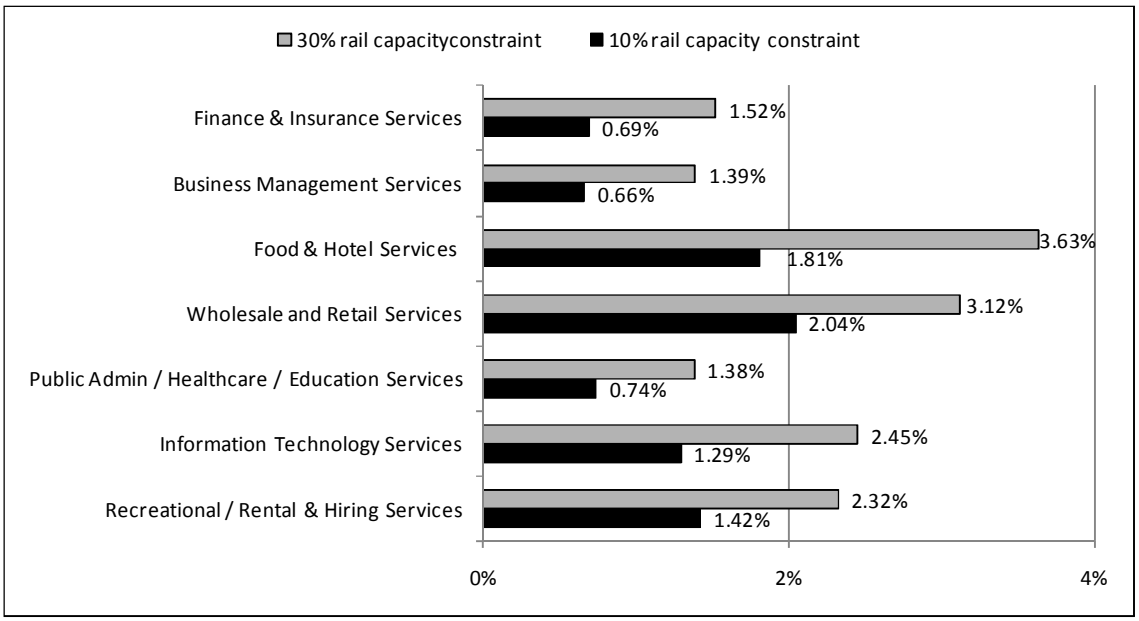


Figure 6.7: Percentage change in total annual employment for each sector under 10% and 30% rail capacity constraint

Comparison of Figure 6.6 and 6.7 suggest that those sectors that are willing to consider higher remuneration packages when traffic condition deteriorates are also the ones that are more likely to indicate that the rising congestion may also affect their employment plans in the short term.

Overall, the survey results suggest that a 10% rail capacity constraint may be associated with a (weighted-average) short term CBD employment impact of about -0.97%[9] ± 0.13% (at 95% confidence interval) per year. On the other hand, a 30% rail capacity constraint may be associated with a (weighted-average) -1.86%[7] ± 0.25% (at 95% confidence interval) reduction in the CBD's labour demand per annum in the short term.

It is again observed that the short term employment impact of the 30% rail capacity constraint is about twice that of the 10% rail capacity constraint. This supports the earlier proposition that CBD employers were only considering the associated increase in AM peak automobile travel time rather than the level of rail capacity constraint when answering the questionnaire.

[9] The annual employment impact of 0.97% and 1.86% are weighted averages based on the employment of the surveyed companies. If the results were weighted using CLUE employment data, the corresponding remuneration impact is 1.01% and 1.93% which are not significantly different.

6.3.3 Longer Term Employment Impacts

The survey did not explicitly capture the employment suppression impact associated with rising rail congestion for the longer term[10]. This is because feedback during the survey pilot test suggests that given the uncertainty, employers are not likely to be able to give a reasonable indication of how their long term remuneration and employment plans may be affected by the rising rail congestion. Therefore, this research used the survey to obtain an indication of the probability that CBD firms may relocate out of the CBD in the longer term due to rising rail congestion. This indication would assist in the subsequent estimation of the agglomeration effects associated with an urban rail constraint in the long term – see Section 9.3.2 for further details.

About 11% of the surveyed companies (based on total employment of all surveyed firms)[11] indicated that they would consider moving out of the CBD in the longer term should the CBD traffic conditions deteriorate in the future. Figure 6.8 shows the proportion of companies in each sector that may consider a possible relocation out of the CBD in the longer term should accessibility into the CBD become more difficult.

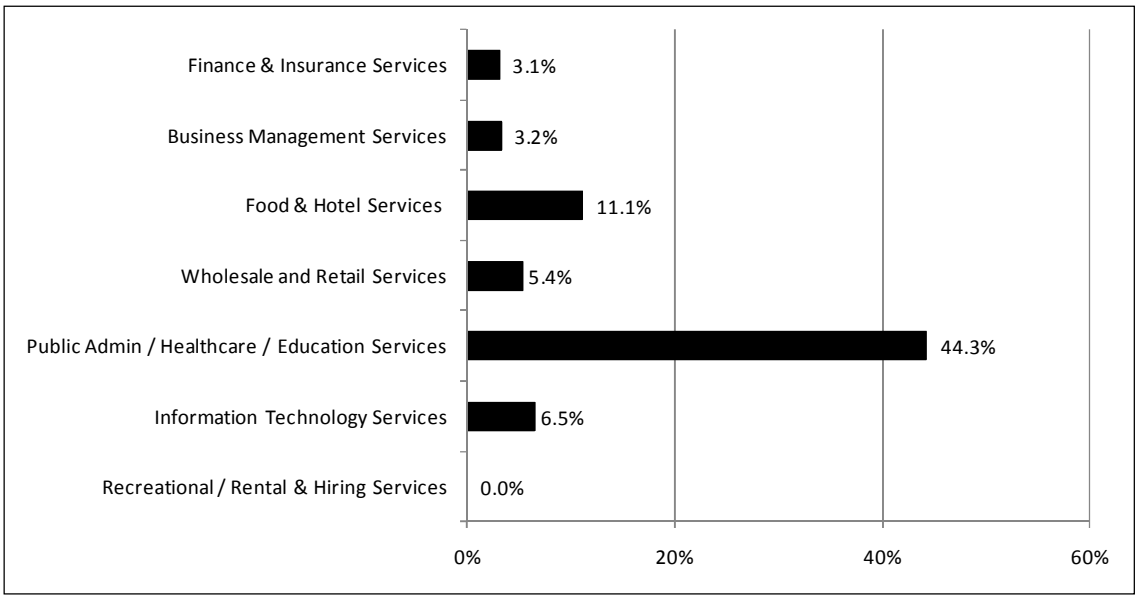


Figure 6.8: Percentage of companies in each sector which are prepared to consider relocating out of the CBD in the longer term should traffic congestion increases

[10] This research therefore estimated the long term agglomeration effects associated with an urban rail constraint using long-run productivity elasticities instead – see Section 9.3.2 for details.

[11] This weighted average was estimated by dividing the total employment of those firms that indicated an intention to relocate with the total employment of all the firms that participated in the survey (i.e. 1,100 employees). This weighted average figure based on employment would provide a better indication of the actual proportion of firms that may relocate out of the CBD in the longer term should traffic condition deteriorate.

For all the sectors except the Public Administration, Healthcare and Education services and the Food and Hotel services sector, less than 10% of the surveyed firms in each industry have expressed a willingness to consider relocating out of the CBD in the longer term should traffic congestion increase. In particular, the Recreational, Rental and Hiring firms surveyed expressed that they will not move out of the CBD regardless of the future traffic situation. Feedback from these sectors suggests that they will stay in the CBD to meet the demand for their services in the area – for example a car rental firm indicated that it is important for them to have an outlet in the CBD to make it easier for their customers to pick-up or return rental cars. This may also explain why these industries have previously indicated the highest percentage in remuneration increase in order to retain or attract new staff when traffic congestion increases.

Slightly more than 40% of the Public Administration, Healthcare and Education services industries have indicated a possible relocation out of the CBD in the longer term. The details of the survey responses suggest that the high rate for this group is because one of the participants which is prepared to move to the fringe of the CBD in the longer term is a Public Administration Office which has a considerable staff strength of 69 (out of the total 183 employees in this group). The other employer in this sector which expressed that they are prepared to relocate is likely to be a Government funded healthcare facility which indicated in the survey that it does not need to be located in the CBD.

Of those companies that indicated a possible relocation, the questionnaire option of “a non-CBD location within Metropolitan Melbourne” was the unanimous choice. Additional comments and feedback provided by some of the participants suggest that the fringe of the CBD (such as the Docklands and Southbank area) is the most likely alternative location. This is consistent with the findings of Section 4.2.2 which provided evidence suggesting that in the last couple of years, Melbourne CBD was actually spreading to the surrounding areas within 10km radius (including Southbank and Docklands area, the rest of the Melbourne LGA and even to the surrounding LGAs such as Yarra and Boroondara).

The spreading trend suggests that some employers are avoiding Melbourne CBD. From the survey results, it appears that one of the possible reasons for doing so could be to avoid congestion. By locating themselves in the fringe of the CBD, these firms enjoy the close proximity to their CBD client base but are not subjected to the same peak hour traffic congestion facing the CBD on a daily basis. This is consistent with the findings of past studies (such as Beeson, 1990, Hansen, 1990, Hanson, 1996, Graham, 2000 and Graham, 2001) which found that firms on urban periphery are able to enjoy positive externalities associated with agglomeration while avoiding many of the higher costs

6.3.4 Assessment - Accuracy of the Survey Findings

The following section evaluates the accuracy of the survey findings.

6.3.4.1 Survey Sample

Neuman (1991) recommended that for large populations (over 150,000 people), a sample size of about 1% is acceptable to yield a representative sample. As reported earlier, the CBD survey achieved a sample size of about 0.6% of CBD employees. While this sample size is smaller than the desired 1% of CBD employees (as suggested by Neuman (1991)), the participation rate across the various industries as well as the findings of the firm size analysis below suggest that the achieved sample size is acceptable. A larger sample is more desirable however not possible due to low survey return as respondents were reluctant to undertake survey (see Section 6.4 and the field report in Appendix C).

Figure 6.9 shows the targeted and actual survey participation rate across industries. The targeted participation level of each industry type in the survey was estimated using the 2006 employment figures from the Census of Land Use and Employment (CLUE) (City of Melbourne, 2006). This was based on the total number of workers employed in each sector expressed as a percentage of the total CBD employment. As shown in Figure 6.9, the distribution of the main survey sample is a reasonable representation of the actual CBD workforce since the actual survey participation rate across the sectors are reasonably close to the targeted participation rate.

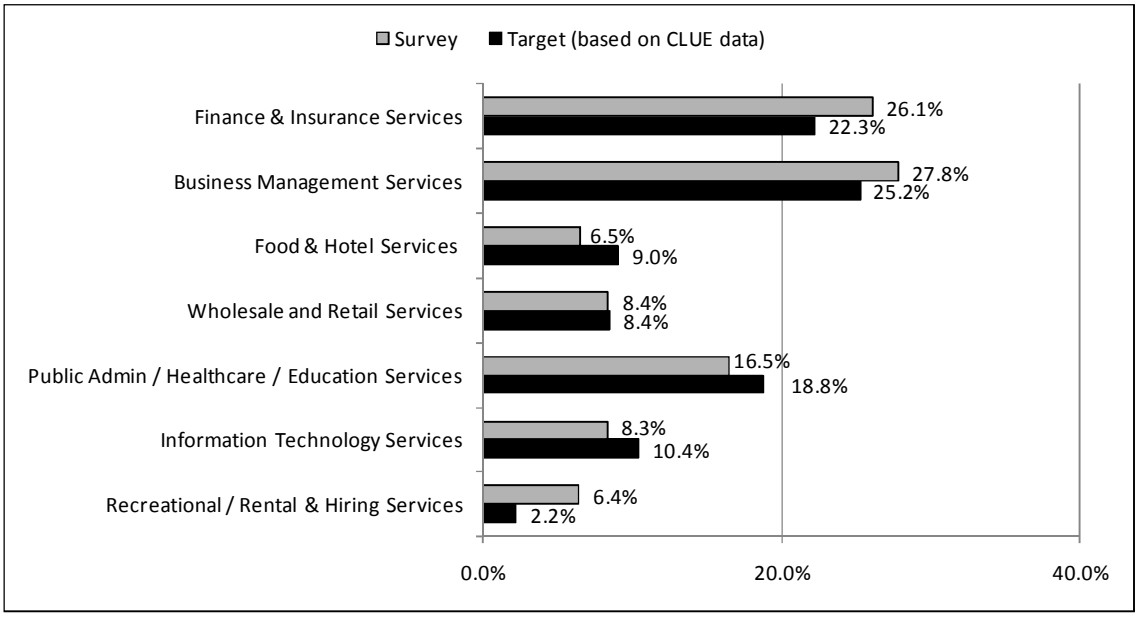
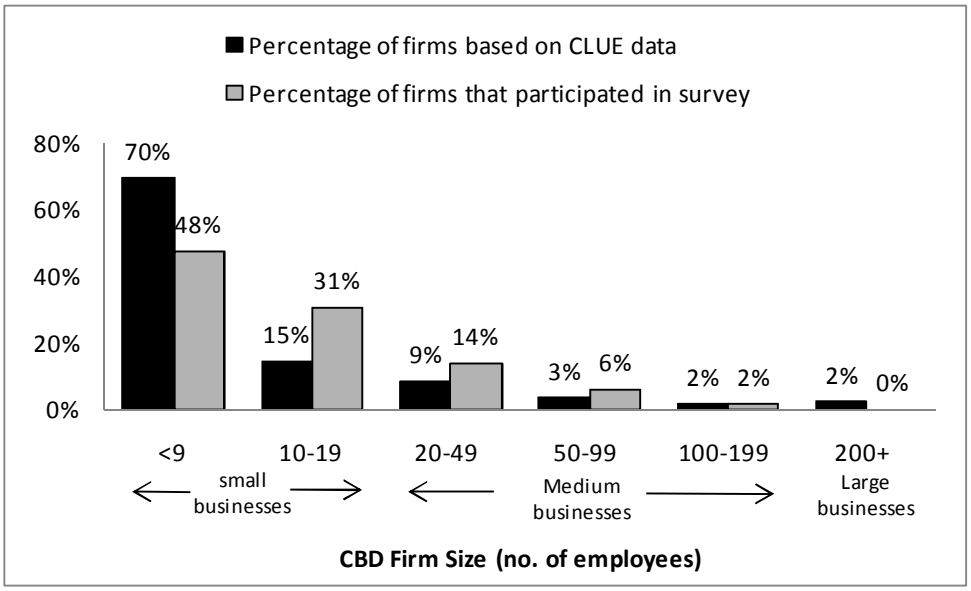


Figure 6.9: Targeted and actual participation rate

Figure 6.10 compares the size distribution of CBD firms across all sectors in terms of the establishment's employment – the black column represents the distribution of the CBD firm sizes based on CLUE data (City of Melbourne, 2009); the grey column represents the distribution of firms that participated in the survey according to their employment figures.



Source: based on City of Melbourne (2009)

Figure 6.10: Size distribution of CBD firms (in terms of employment) based on CLUE data and actual survey participation

This distribution is in accordance to the format that CLUE data was provided. According to Australian Bureau of Statistic's (ABS) (2001a) definition, a small business is defined as a business employing less than 20 employees. ABS (2001a) defined medium businesses as "businesses employing 20 or more people but less than 200 people" and large businesses are those that "employ more than 200 employees".

As shown in Figure 6.10, about 80% of the firms that participated in the survey are small businesses while the remaining 20% are medium businesses. This is in the same "ball park" as the existing proportion of small (84%) and medium (14%) businesses in the CBD according to CLUE data (City of Melbourne, 2009). While no large businesses participated in the survey, their small proportion (2%) suggests that their absence is not likely to undermine the representation of the survey sample in terms of firm size consideration. Given that small and medium businesses collectively represent 98% of the total existing CBD establishments, this suggests that the overall survey participation level in terms of firm size distribution is representative of the existing CBD firm establishment situation.

It is also noted that there are significant differences in the proportion of CBD's small businesses with 9 or less employees and with 10 -19 employees based on CLUE data and the actual survey participation. These differences are due to the format that the CLUE data is structured; the differences would be smaller (less than 5%) if the small businesses were grouped into "10 or less employees" and "11 – 19 employees" as there is a handful of surveyed companies which employ a total of 10 workers. Regardless, the difference in the proportion of firms within the small businesses category is not envisaged to distort the survey results.

The above analysis suggests that the achieved survey sample is a reasonable representation of the CBD both in terms of the distribution across sectors as well as firm sizes. The analysis shown in Figure 6.9 suggests that the actual survey participation levels across the sectors are reasonably close to the targeted participation rate. In terms of firm sizes, while only small and medium businesses participated in the survey, analysis using CLUE data (City of Melbourne, 2009) suggests that the survey findings are representative of 98% of the existing CBD establishments.

6.3.4.2 Assessing Remuneration Impacts

As highlighted earlier, ABS (2006i) data indicates that the lower income earners such as labourers, workers and technicians working in the CBD are drawing an average weekly income of about $825 while the CBD Professionals and Managers are earning on average about $1,430 per week. Overall, the average wage of a CBD employee (weighted based on employment) is about $1,140 per week.

The survey results suggest that CBD employers are willing to raise their annual remuneration by about 2.09% on average (weighted) to compensate for the higher level of commuting difficulty into the CBD associated with a 10% rail capacity constraint. Based on an average weekly income of $1,140, this translates to an average increase of about $24 in weekly remuneration per employee.

Assuming that a typical CBD employee works 5 days per week and that each worker makes on average a trip to and from work each weekday, the $24 increment in weekly remuneration essentially translates to an average compensation of about $2.40 per trip. Australian Transport Council (ATC) (2006) recommends a value of $15/hour be adopted as the value of private time (VOT) for use in economic appraisal of transport proposals in Australia. Based on the $15/hour VOT, the $2.40 compensation is equivalent to the value of a 9.5 minute period.

In the survey, it was indicated hypothetically to the participants that the 15% increase in travel time to work (associated with 10% rail capacity constraint) would translate to an increase of about 1-10 minutes[12] (depending on the origin of the employee). It appears from the above results that the employers may have (consciously or unconsciously) used the 10 minute increase in travel time as the benchmark to determine how much to compensate their employees for the increase in travel time to work. The above analysis also suggests that the remuneration impacts found in the survey is considered generally plausible using this independent assessment.

[12] As shown in Table 5.11, under a 10% rail capacity constraint, the increase in travel times into the CBD is about 1-8 minutes. To make it easier for the participants, this was rounded up to 1-10 minutes. A similar rounding up to 5 – 15 minutes (from the original 2-10 minutes) was also carried out for the 30% rail capacity constraint scenario to facilitate the survey.

The survey results also suggest that CBD employers are willing to raise their annual remuneration by about 3.75% or $42 in average weekly remuneration under the higher traffic congestion level associated with a 30% rail capacity constraint. Using the same assumptions mentioned above, this translates to an average compensation of about $4.20 per trip. Based on ATC's (2006) VOT of $15/hour, this is equivalent to the value of a 17-minute period.

In the survey, it was indicated hypothetically to the participants that the 25% increase in travel time to work (associated with 30% rail capacity constraint) would translate to an increase of about 5 -15 minutes (depending on the origin of the employee). Again, it appears from the above results that the CBD employers may have (consciously or unconsciously) used the 15 minute increase in travel time as indicated in the survey to estimate the compensation for the increase in travel time associated with a 30% rail capacity constraint. The above analysis further supports the earlier preposition that the remuneration impacts found in the survey is plausible based on this independent assessment.

6.3.4.3 Assessing Short Term Employment Impacts

Figure 6.11 compares the short term employment suppression impact associated with a 10% urban rail capacity constraint obtained from the survey against those estimated based on the output from MITM (Chapter 5).

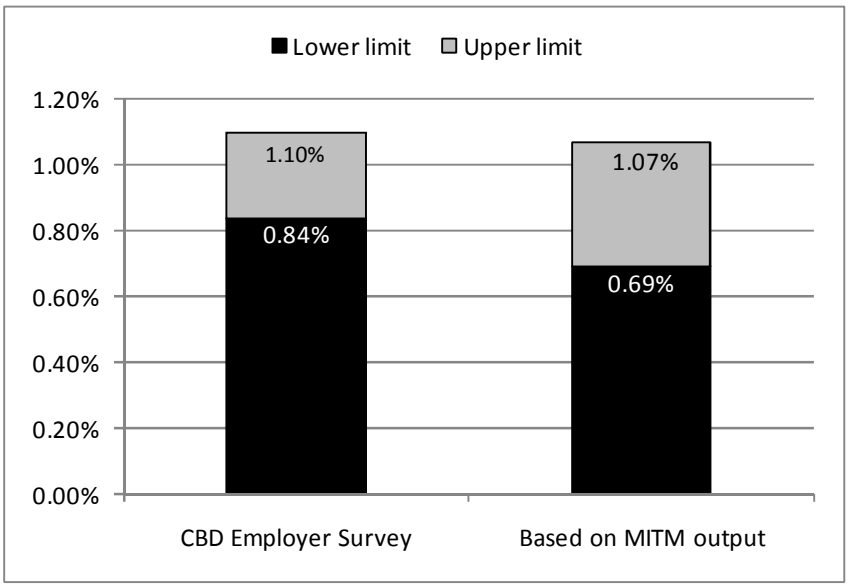


Figure 6.11: Employment suppression impact associated with a 10% rail capacity constraint estimated from survey and MITM output – short term

As shown in Table 6.1, the survey concluded a weighted-average CBD labour demand impact of -0.97% ± 0.13% (at 95% confidence interval) in the short term for a 10% rail capacity constraint – i.e. -0.84% to -1.10%. This surveyed impact of -0.97% is observed to be within the short term labour supply impact estimated in Chapter 5 (i.e. -0.69% to -1.07%).

Based on the above assessment, the weighted-average employment suppression impact value of -0.97% (associated with a 10% rail capacity constraint) obtained in the survey is considered plausible. The above comparative assessment of the estimates from the two approaches supports the earlier suggestion that the -0.69% to -1.07% range of employment suppression impact is a reasonable estimate for Melbourne CBD associated with a 10% urban rail capacity constraint.

6.4 Key Observations and Feedback

In the course of conducting the main survey, the following observations and feedback were received and are described here because they provide some colourful detail which informs the analysis undertaken.

a. Major organisations such the City of Melbourne and Victorian Employers' Chamber of Commerce and Industry (VECCI) have indicated that CBD companies and workers are constantly being bombarded by surveys. They highlighted that even their own surveys are not well-received by the CBD firms due to survey fatigue. Hence, they were unwilling to assist in the survey as they anticipate that CBD employers are not likely to participate actively in surveys that are carried out as part of postgraduate research programmes due to survey fatigue.

b. The Melbourne Transport Management Association whose members include representatives from several major companies located in the CBD responded that the group is not interested during this period of economic uncertainty in participating in research[13]. This view was shared by the other major companies contacted in the survey process. The general consensus of these companies was that the media has under-reported the impact of the current global economic crisis; their sole focus at the time was to improve their firms' performance. This also explains the high rejection rates (to participate) especially amongst the bigger firms.

c. Larger firms have shown less interest in participating in the survey because their client market is largely located within the CBD and they will not shift out of the CBD regardless of traffic congestion levels - this was also one of the main reasons for refusal to participate given by the larger companies. This is in line with the evidence found in the recent work of O'Huallachain and Leslie (2007), Davis and Henderson (2008) and Strauss-Khan and Vives (2009) which suggested that HQs and major establishments tend to locate in CBDs because of the economies of scale in provision of business services and to capitalise on other externalities (such as knowledge externalities and other externalities on the input and labour markets).

[13] This research was under taken just after the commencement of what have been termed the "global financial crisis".

d. The bigger firms, especially those in the professional fields have also highlighted that they are located in the CBD because that is where their clients are largely located; hence the demand for the skill sets and expertise of their employees are largely found within the CBD. Hence regardless of the congestion level, these professional employees would still work in the CBD. These larger firms therefore have less concern about rising traffic impact on their employment plans and business costs.

e. In addition, the larger firms have also indicated that the feedback from their staff who were engaged in overseas' projects or who were from other cities / countries indicated that the AM peak traffic congestion in Melbourne CBD is not as bad as some other cities and is still tolerable. This may suggest that their employees (especially the professionals) are less likely to relocate to other cities or other countries which may further lower the larger firms' concern about rising traffic impact on their employment plans.

f. Several Human Resource Directors / Managers as well as recruitment firms have suggested that the current economic situation has essentially created "an employers' market" environment where the employers hold the view that their employees would hold on to their jobs regardless of the rising cost of commuting. This may have lowered the participation rate of the CBD employers especially the larger firms.

g. Recruitment firms have also suggested that larger companies have natural attractiveness (such as better staff development programmes) to retain and attract staff. They explained that such natural attractiveness and the prevailing "employers' market" environment meant that larger firms are generally not worried about CBD congestion impact on their employment plans. The prevailing "employers' market" condition may however suggest that when the economy recovers, the impact of the rising rail congestion to the cost of doing business in the CBD may be higher.

h. The small and medium size firms on the other hand, tend to be more willing to participate in the survey because their smaller work force means that losing staff to a congestion impact (for example the staff are late for work due to traffic congestion or decide to find a job closer to home) is more detrimental to their overall business operation. In addition, several of the smaller firms have suggested that they are also less competitive in terms of remuneration packages compared to the bigger players. Hence they showed more interest in retaining or attracting new staff. This is evident in the survey results.

i. The survey results showed that in general about 10% of the surveyed companies are willing to consider relocating outside the CBD. Since most of the companies that participated in the survey are the small and medium establishments, the result suggests that companies of these sizes may be more willing than the big firms to move out of the CBD. This is in line with the findings of O'Huallachain and Leslie (2007) who found that smaller firms that provided professional services were prepared to be located in suburban areas as they mostly provide standardised services for accessibility-dependent commercial and residential clients; large establishments in the same sectors were however found to concentrate in the CBD in order to exploit economies of scale so as to produce sophisticated and customised services.

j. The surveyed companies have provided feedback that should they relocate out of the CBD, the fringe of the CBD would be their preferred choice as their client market is largely located within the CBD. This suggests that the client base of firms is a major factor that influences the location decisions of companies. This is consistent with the findings of Davis and Henderson (2008) and Strauss-Khan and Vives (2009).

k. Feedback provided by the participants suggests that the fringe of the CBD is the preferred choice of relocation. This is also consistent with the findings of past studies (such as Beeson, 1990, Hansen, 1990, Hanson, 1996, Graham, 2000 and Graham, 2001) which found that firms on urban periphery are able to enjoy positive agglomeration externalities while avoiding many of the higher costs.

6.5 Summary

This chapter presents the analysis of the results from the Melbourne CBD employer survey. The objective of the survey was to gather information from employers regarding the potential impact that rail congestion may have on their businesses in the CBD. The primary survey represents another approach used by this research to estimate the potential employment suppression impacts associated with an urban rail capacity constraint.

Overall, about 250 emails and 600 telephone calls were made during the main survey which was conducted from 10th August 2009 to 30th September 2009. A total of 65 companies which employ some 1,110 employees participated in the survey. This yielded a sample size of about 0.6% of CBD employees. While this is smaller than the desired 1% of CBD employees, the participation rate of firms across sectors and the results of the CBD firm size analysis suggest that the achieved sample is reasonably acceptable and representative of 98% of the existing CBD establishments.

The survey responses suggested that a 10% rail capacity constraint may possibly result in a 2.09% ± 0.15% (at 95% confidence interval) increase in CBD annual remuneration and a -0.97% ± 0.13% (at 95% confidence interval) fall in annual CBD employment in the short term. This short term employment impact is considered plausible and is within the 0.69% - 1.07% range estimated in Chapter 5. Comparative assessment of the different approaches support the earlier proposition that the 0.69% - 1.07% range of employment suppression impact is a realistic estimate for Melbourne CBD associated with a 10% rail capacity constraint.

Observations from the survey suggested survey fatigue and the poor economic climate as primary reasons for the low participation rate of the survey. The survey response also indicated that larger establishments showed less interest than small and medium size firms in participating in surveys. This is because larger firms are less concerned about the rising congestion levels since they have better facilities to retain or attract staff and their employees are largely made up of professionals who have lower employment mobility in a localised sense within the city. In addition, these firms are also less willing to shift out of the CBD as their client market is largely based in the CBD. Overall, the survey responses suggested that the client base of firms play a major role in location decisions.

CHAPTER 7

Secondary Data Analysis

7.1 Introduction

This chapter reports the findings of the secondary data analysis which has been conducted using data from international and Australian cities. This analysis aims to explore how the employment sizes of Central Business Districts (CBD) correlate with their productivity as well as their urban rail capacity provision. This is to benchmark findings from the other components of this research. In addition, this analysis using aggregate city wide data from international and Australian cities also represents another approach[1] used by this research to estimate the potential employment suppression impacts associated with dis-agglomeration effects in urban rail. Figure 7.1 shows how this secondary data analysis (shown boxed in red) fits into the overall research methodology.

This analysis largely made use of data from the International Association of Public Transport's (UITP) (2001) Millennium Cities Database. This is a database that contains information on demographics, economics and urban structure as well as private and public transport supply, use and cost of 100 cities, compiled by UITP in collaboration with Professors Jeff Kenworthy and Felix Laube at Murdoch University (Vivier, 2001). According to UITP's (2001) definition, the data has been collected on a metropolitan area basis. For example, the Melbourne City indicated in UITP (2001) essentially refers to Melbourne metropolitan area[2].

[1] As mentioned in the research methodology (Chapter 3), this research measures the agglomeration effects in urban rail using 2 measures. The potential employment suppression impact is one of the measures. This secondary data analysis is the 3rd approach explored in this research to estimate the potential employment suppression impact associated with an urban rail capacity constraint.

[2] The Australian Bureau of Statistics refers to Melbourne Metropolitan Area as Melbourne Statistical Division.

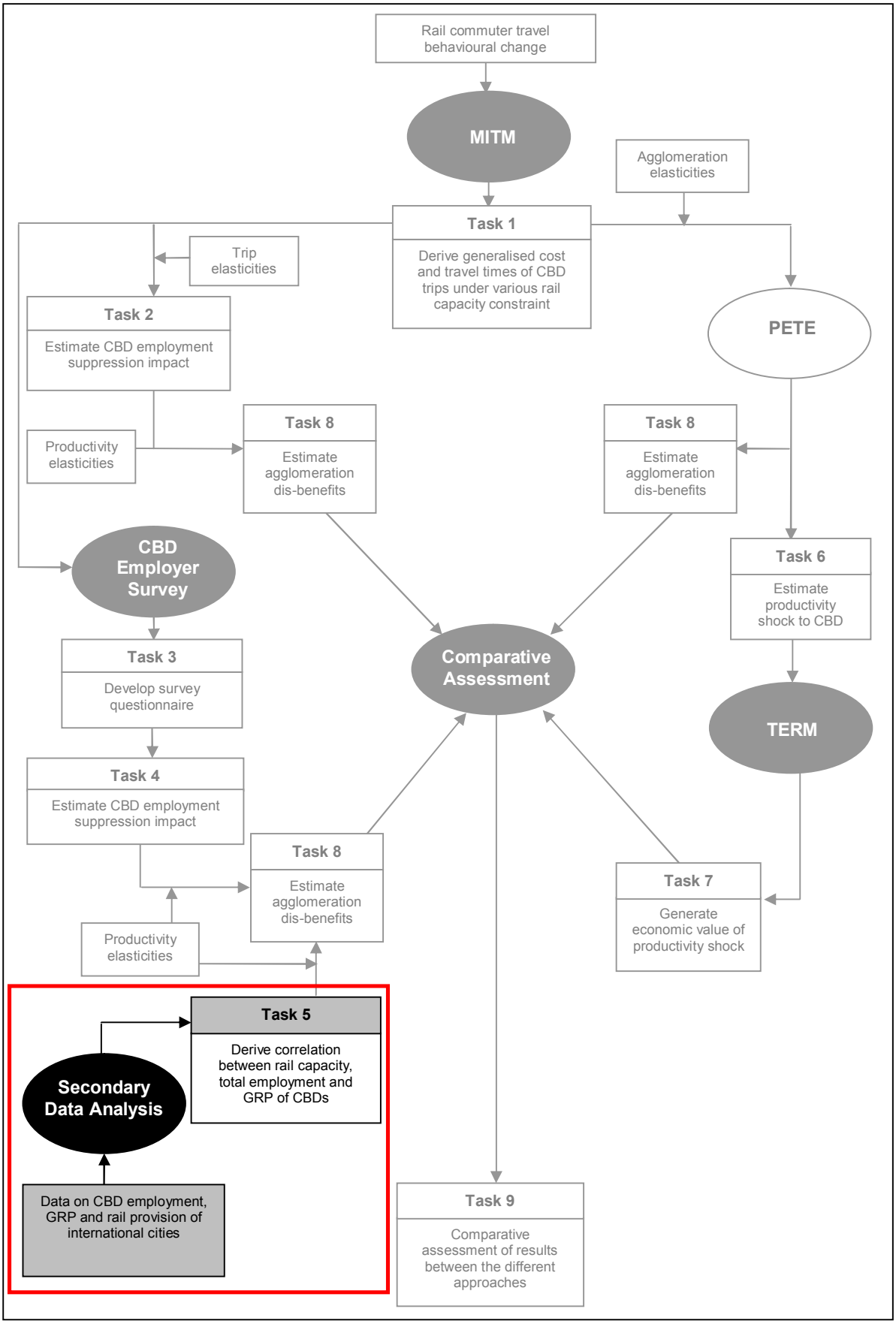


Figure 7.1: Research focus of Chapter Seven

This chapter is organised in the following order.

- **Section 7.2 -** **Selection of Cities** explains the criterion adopted to select the cities short-listed for the exercise.
- **Section 7.3 -** **Analysis Approach** outlines the methodology adopted in the analysis.
- **Section 7.4 -** **Hypotheses** reports on the comparative assessment of Australian CBDs against their international peers to hypothesise the relationship between the employment size, urban productivity and rail capacity provision of CBDs.
- **Section 7.5 -** **Statistical Assessment** tests the validities of the hypotheses suggested in Section 7.4 using statistical tools.
- **Section 7.6 -** **Critique of Data Set** examines the strengths and weaknesses of the Millennium Cities Database.
- **Section 7.7 -** **Summary** concludes the chapter.

7.2 Selection of Cities

Given the variation in infrastructure development and economic progress of various cities, it was not meaningful to compare all the cities featured in UITP (2001). As the focus of this research is to examine agglomeration effects of urban rail, it is a pre-requisite for the selected cities to possess the following qualities.

- Have achieved good economic success.
- Have a good commuter rail system.

Non-rail cities featured in UITP (2001) such as Delhi (India) and Ho Chi Minh City (Vietnam) are, for example, not appropriate comparators. This is because these non-rail cities are largely developing cities and their lower economic status (in 1995) cannot be totally attributed to the absence of an urban rail system.

This analysis therefore selected 20 international cities[3] (including Melbourne) for assessment, based on the following two considerations.

1. The selected cities include largely the top 10 cities from the Mercer Quality of Living Survey (Mercer Consulting Group, 2009), The Economist's World's Most Liveable Cities (The Economist Intelligence Unit, 2009) and Monocle's Most Liveable Cities Index[4] (Monocle, 2009). The rationale was that all three renowned surveys have considered public transportation (PT) as a criterion in their ranking. It is reasonable to assume that their good commuter rail systems have played an important role in supporting their CBD's employment and economy. It is assumed in adopting these criteria that liveability measured from the viewpoint of these leading indices equates to success.

2. The selected cities also include 'affluent' cities with good train systems including London, New York and Paris, which were voted as having the best PT systems in a poll of international tourists conducted by the TripAdvisor company in 2006 (Transport for London, 2006) as well as Singapore, Hong Kong and Tokyo, which are three of the most 'affluent' Asian cities with good train systems. The rationale here is to explore if quality rail systems in these cities have contributed to their economic success.

Based on the above criteria, 10 European, 4 Australian, 3 Asian and 3 North American cities were selected. They are shown in Table 7.1 (in alphabetical order).

Table 7.1: Cities selected for analysis

s/no	Cities	s/no	Cities
1.	Brisbane (Australia)	11.	New York (USA)
2.	Brussels (Belgium)	12.	Paris (France)
3.	Copenhagen (Denmark)	13.	Perth (Australia)
4.	Dusseldorf (Germany)	14.	Singapore (Singapore)
5.	Frankfurt (Germany)	15.	Stockholm (Sweden)
6.	Helsinki (Finland)	16.	Sydney (Australia)
7.	Hong Kong (PR China)	17.	Tokyo (Japan)
8.	London (United Kingdom)	18.	Toronto (Canada)
9.	Melbourne (Australia)	19.	Vancouver (Canada)
10.	Munich (Germany)	20.	Vienna (Austria)

[3] Section 7.5.1.1 explains why a sample size of 20 was chosen for this analysis.

[4] This analysis was carried out in the 2nd half of 2009. Hence, the cities have been chosen largely from the 2009 lists of these surveys.

7.3 Analysis Approach

This analysis has been conducted using the following approach. A more detailed explanation of each step is presented in Appendix D of this thesis.

Step 1: Estimation of CBD employment Size, Concentration and GRP

UITP (2001) defines a CBD as "the area with the most significant employment concentration in the metropolitan area lying mostly at the geographic heart of the region"[5]. This step estimates the employment size and Gross Regional Product (GRP) of each city's CBD using data on the job density, the proportion of jobs within the CBD and the metropolitan GRP per capita[6] from UITP (2001). The employment size and GRP of each CBD are estimated using Equation 7.1 and 7.2 respectively. Equation 7.3 estimates the employment concentration (i.e. the number of workers per unit area) of the CBD.

$$\text{CBD employment size} = \left(\frac{\text{Metropolitan Population}}{\text{Population density}}\right) * \text{job density} * \text{proportion of jobs in CBD} \quad \text{(Equation 7.1)}$$

$$\text{CBD GRP} = \text{CBD employment size} * \left(\frac{\text{Metropolitan GDP per capita} * \text{Metropolitan Population}}{\text{Metropolitan Employment}}\right) \quad \text{(Equation 7.2)}$$

$$\text{CBD employment concentration} = \text{CBD employment size} / \text{CBD area} \quad \text{(Equation 7.3)}$$

With reference to Equation 7.1, the division of the total metropolitan population by the population density would yield the total urbanised area of the metropolitan area. The product of the metropolitan urbanised area with its job density would give the total employment size of the city. This is then factored with the percentage of jobs within the CBD (from UITP (2001)) to estimate the total number of employees working in the CBD.

[5] UITP (2001) highlighted that the definition of urban boundary is one key area of challenges to maintain consistency – see Section 7.5 for a critique of UITP database.

[6] UITP (2001) term this as the metropolitan Gross Domestic Product (GDP) per capita.

The metropolitan GRP per capita (from UITP (2001)) is multiplied by the metropolitan population to yield the GRP of the metropolitan area. The division of the GRP figure by the total employment size of the city would give an indication of the GRP contribution per worker. The latter is then multiplied by the CBD employment size to derive the CBD GRP as shown in Equation 7.2. As CBDs typically have a higher concentration of knowledge-based industries compared to the overall metropolitan area, the GRP contribution per metropolitan worker is envisaged to yield a conservative estimate of the CBD's GRP.

As shown in Equation 7.3, the CBD employment concentration or the number of workers per unit area in the CBD was estimated based on the CBD employment size and physical area. The areas of the CBDs, except that of Dusseldorf and Helsinki, were obtained from Kenworthy and Laube (1999a), which is a continuation of the UITP (2001) project by Professors Kenworthy and Laube. The use of CBD area information from Kenworthy and Laube (1999a) ensured consistency with the urban boundary definition that the UITP (2001) data set was based on. The CBD areas of Dusseldorf and Helsinki were obtained via personal communication with the City of Dusseldorf and City of Helsinki respectively.

Step 2: Estimation of daily rail capacity provision serving the CBD

In this step, the daily rail capacity provided to serve each metropolitan area was first estimated as follows.

<u>Estimation of total carrying capacity per rail car</u>

a. The average seating capacity per rail car was derived based on the total rail car seat-km per capita and the rail car-km per capita (from UITP (2001)) as per Equation 7.4.
b. The total carrying capacity per rail car was then estimated by factoring the average seating capacity (from step a) with a standing / seating ratio – see Equation 7.5. The standing / seating ratio was assessed using the rolling stock information from the respective rail operators and transport agencies.

$$\textit{Average seating capacity / rail car} = \left(\frac{\textit{Total rail car seat-km per capita}}{\textit{Rail car-km per capita}} \right) \qquad \text{(Equation 7.4)}$$

$$\textit{Total carrying capacity / rail car} = (\textit{Average seating capacity / rail car}) * \left[1 + \left(\frac{\textit{Standing capacity}}{\textit{Sitting capacity}}\right)\right] \qquad \text{(Equation 7.5)}$$

Estimation of total number of rail car vehicle trips per day

c. The product of the rail car-km per capita and the residential population of each city (from UITP (2001)) yields the annual rail car-km travelled in each city (Equation 7.6).

d. The output from step (c) was divided with the working day annualisation factor to compute the daily rail car-km travelled in each city (Equation 7.7). Connex Melbourne (2009) recommended an annualisation factor of 295 for Melbourne - this value was adopted for the other cities.

e. The total number of rail car trips made per day was then calculated by dividing the daily rail car-km travelled (from step (d)) with the average rail trip length using Equation 7.8. The average rail trip length was derived based on the total rail network rail route length and total number of rail lines in the network from the respective rail operators. This is represented in Equation 7.8.

$$\textit{Annual rail car-km travelled} = \textit{rail car-km per capita} * \textit{metropolitan population} \qquad \text{(Equation 7.6)}$$

$$\textit{Daily rail car-km travelled} = \frac{\textit{Annual rail car-km travelled}}{\textit{Annualisation Factor}} \qquad \text{(Equation 7.7)}$$

$$\textit{Total rail car trips per day} = \frac{\textit{Daily rail car-km travelled}}{\textit{Average rail trip length}} \qquad \text{(Equation 7.8)}$$

The product of the total carrying capacity per rail car (from step b) and the total number of rail car trips per day (from step e) would yield the daily rail capacity provided to serve each city (Equation 7.9).

An assessment based on the rail network configuration was made to estimate the proportion of the daily rail capacity serving each city that enters the CBD. For most cities where the rail lines run radially from the CBD, this research assumes that 50% of the city's daily rail services enter the CBD – the other 50% are leaving the CBD. For the remaining few cities (such as London and Toronto) whose rail network include non-radial lines, the proportion of the daily rail capacity serving the CBD was estimated based on the amount of radial and non-radial services according to their rail service timetables or network coverage. Equation 7.10 estimates the daily rail capacity provided to serve each CBD.

Daily rail capacity provided to serve each city
*= total carrying capacity per rail car * total number of rail car trips*

(Equation 7.9)

Daily rail capacity provided to serve each CBD
*= Daily rail capacity provided to serve each city * proportion of city rail network that serves CBD* (Equation 7.10)

Step 3: Analysis

The case study adopted in this research is an Australian CBD. Therefore, as part of this secondary data analysis, a comparative assessment of CBDs in Australia against those in international cities was carried out to hypothesise the inter-relationship between the employment of CBDs, their productivities and the daily rail capacity provided to serve them. These hypotheses are presented in Section 7.4. The Statistical Package for the Social Sciences (SPSS) software was used to test the validity of these hypotheses. The results of these analyses are discussed in Section 7.5.

7.4 Hypotheses

This section hypothesises the following:

- the significance of employment concentration as a predictor of a CBD's GRP and urban rail provision compared to total employment size
- the relationship between the employment size, GRP and CBD rail capacity provision.

These hypotheses are derived via a comparative assessment of these parameters for Australian CBDs against their international peers. The hypotheses are validated using statistical assessment in the next section.

The data for the CBD of each city, as computed based on the approach outlined in Section 7.3, are summarised in Table 7.2. The estimates for the four Australian CBDs are shown in the first 4 rows of the table; rows 5 – 20 present the corresponding estimates for international CBDs.

Table 7.2: Summary of CBD employment size, GRP and daily rail capacity provision of international and Australian cities

s/no	City	CBD employment ('00,000 workers)	CBD area (km^2)	Employment Concentration ('00,000 workers / km^2)	CBD GDP ($billion-1995 USD)	Daily rail provision entering CBD (00'000 pax trips)
1	Melbourne	1.23	3.50	0.35	$6.36	5.86
2	Brisbane	0.74	2.50	0.30	$2.67	3.65
3	Perth	1.00	7.50	0.13	$5.24	1.22
4	Sydney	2.03	4.20	0.48	$10.73	12.83
5	Brussels	1.66	3.11	0.53	$7.09	6.37
6	Copenhagen	1.29	4.67	0.28	$9.11	13.86
7	Dusseldorf	1.40	4.20	0.33	$8.56	0.77
8	Frankfurt	1.09	2.33	0.47	$7.29	6.43
9	Helsinki	0.93	2.50	0.37	$5.38	6.15
10	Hong Kong	1.89	1.10	1.72	$9.20	44.50
11	London	10.48	29.78	0.35	$43.94	51.30
12	Munich	2.79	8.03	0.35	$26.28	15.29
13	New York	20.96	23.04	0.91	$137.03	156.93
14	Paris	8.90	29.00	0.31	$82.13	160.85
15	Singapore	2.78	7.00	0.40	$13.98	13.62
16	Stockholm	1.12	4.14	0.27	$7.69	12.17
17	Tokyo	25.00	42.20	0.59	$209.50	672.57
18	Toronto	1.50	1.81	0.83	$5.81	13.30
19	Vancouver	1.15	3.36	0.34	$6.16	2.13
20	Vienna	1.00	2.85	0.35	$7.38	12.02

Source: Developed from UITP (2001), Connex Melbourne (2009), MetLink (2008), Transperth (2009a, 2009b), Brisbane CityTrain (2009a, 2009b), CityRail (2009a, 2009b), Wikipedia (2009), STIB (2009), DSG (2009), Rheinbahn (2009), VFG (2009), Helsinki City Transport (2009), MTR (2009), Transport for London (2009), MVV (2009), Metropolitan Transportation Authority (2009a, 2009b), SMRT (2009a, 2009b), Swiss Federal Railways (2009), Tokyo Metro (2009), TOEI Subway (2009), Transit Toronto (2008), TransLink (2009), Wiener Linein (2009), Kenworthy and Laube (1999a).

As shown in Table 7.2, the 20 CBDs selected for this analysis show a good spread of employment sizes, GRP values and daily rail capacity provision. This suggests that the 20-cities sample provides a good basis for this exercise.

Figure 7.2 compares the CBD daily rail capacity provision and employment sizes of the 4 Australian cities against the international cities, as at 1995.

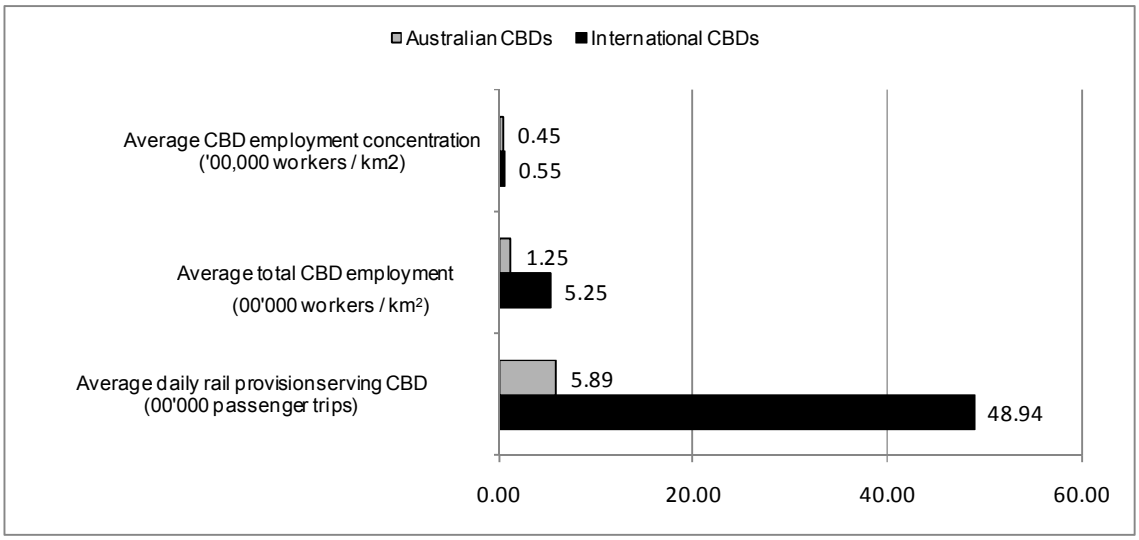


Figure 7.2: Comparison between the CBDs of Australian and other international cities

As shown in Figure 7.2, the average employment concentration of Australian CBDs in 1995 was about 45,000 workers/km^2. CBDs in the other international cities were found to be about 20% denser, with an average employment concentration of about 55,000 workers/km^2 in 1995.

Not only are they denser, the CBDs of the international cities also had larger employment sizes. On average, an Australian CBD employed about 125,000 employees in 1995 while the CBDs of the international cities had an average labour force of about 520,000 employees in the same period. This is about 4 times the average employment size of Australian CBDs.

Figure 7.2 also shows that the average rail capacity provided to serve the CBDs of international cities in 1995 was equivalent to about 4.9 million daily passenger trips. This is about 8 times the average rail capacity provision (of 0.6 million passenger trips) for Australian CBDs at that time. It appears from this comparative assessment that total CBD employment size has a stronger association with the amount of rail capacity provided to serve the CBD than does employment concentration.

Examination of the dataset provided in Table 7.2 provides further evidence to support this proposition. For example, as shown in Table 7.2, the total CBD employment of London City in 1995 was about 1.05 million; with a 30 km^2 CBD, this translated to a CBD employment concentration of about 35,185 employees/ km^2. This is comparable to the employment concentration of Melbourne CBD – 35,145 employees/ km^2 – which has a land area of only 3.5km^2. However, the daily rail capacity provided to serve London CBD in 1995 was about 9 times higher than that provided to serve Melbourne CBD which had a total employment of 123,000 in 1995; the latter was noted to be about one ninth the total employment of London CBD.

Table 7.2 also suggests that CBDs with larger employment sizes tend to have higher GRPs. However, the association of GRP with employment concentration may not be as straightforward. This is again evident between Melbourne and London CBD. It is observed that London CBD's GRP is about 7 times that of Melbourne CBD in 1995 despite both CBDs having the same employment concentration. It therefore appears that employment concentration is a less significant predictor of a CBD's productivity and urban rail provision than total employment size. This hypothesis is validated using statistical assessment in the next section.

Figure 7.3 shows a combined graph of the CBD's GRP and total daily rail capacity provision against the total CBD employment for the international CBDs (black solid curves) as well as the Australian CBDs (grey dotted curves). The arrows along the 2 Y-axes represent the GRP values and the daily rail provision respectively in increasing order. The horizontal axis represents the total CBD employment of each city. The CBDs of New York, Tokyo, London and Paris were omitted from this plot as their inclusion tends to exaggerate the differences between the international and Australian CBDs.

.

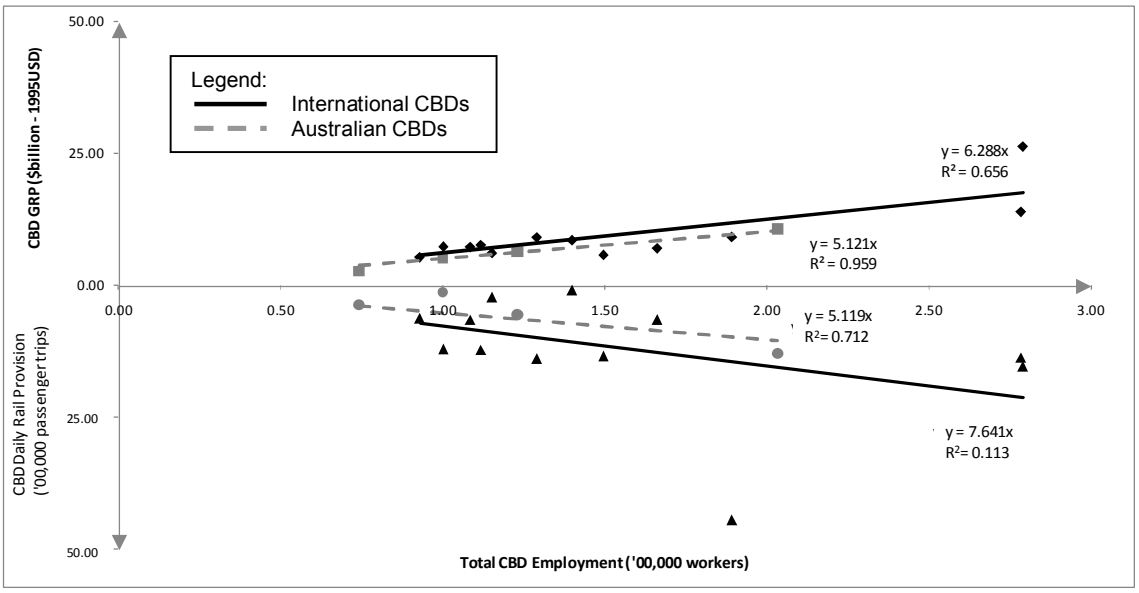


Figure 7.3: Plot of CBD's GRP and daily rail capacity provision against total CBD employment [7]

Figure 7.3 suggests that the international cities generally provide more rail capacity to serve their CBDs as compared to the Australian cities. The ratio of the coefficients of the 2 CBD daily rail provision curves for international cities and their Australian peers shown in Figure 7.3 suggests that international cities are likely to provide 1.5 times (i.e. =7.641/5.119) more rail capacity than Australian cities to serve their CBDs of a given size.

The above figure also suggests that the CBDs of international cities generally achieve a higher GRP value as compared to their Australian peers. The ratio of the coefficients of the 2 CBD GRP curves for international cities and their Australian peers shown in Figure 7.3 suggests that international CBDs of a given size are likely to be 1.2 times (i.e. =6.288/5.121) more productive than Australian CBDs of the same size. This may suggest the presence of higher productivity due to agglomeration effects associated with urban rail. Overall, it appears from Figure 7.3 that CBDs with larger employment size are associated with a higher level of urban rail provision and higher productivity gains. However, the validity of this hypothesis requires statistical testing. This is carried out in the next section.

[7]Figure 7.3 is meant only to illustrate the above proposition that international CBDs have higher employment, GRP and rail capacity provision compared to Australian CBDs. It is not meant for statistical assessment of the relationship between the variables; hence the low R^2 value is immaterial.

7.5 Statistical Assessment

This statistical assessment is presented in the following sequence.

- **Section 7.5.1 - Assessment Framework** outlines the approach and sample size adopted in this statistical analysis.
- **Section 7.3 - Multiple Regression** presents the results of the stepwise regression.
- **Section 7.4 - Elasticity Evaluation** reports the elasticities between variables.

7.5.1 Assessment Framework

Statistical analysis was carried out using SPSS. The aim of the statistical analysis was to investigate the relationship between CBD employment size and concentration, urban productivity and rail capacity provision. Multiple regressions were first carried out with the natural logarithmic transformed values of these parameters to explore whether these variables could be fitted into a Production Function model. The aim is to test the presence of agglomeration economies and to assess the significance of each independent variable in predicting the dependent variable. The variables used in this analysis are shown in Table 7.3. A constant is considered in the regression model to take into account the scaling effects of the parameters. Linear regressions were conducted thereafter to examine the direct correlation between the significant variables. The coefficients estimated by the model essentially represent the elasticities between these variables.

Table 7.3: Variable descriptions

	Variable	Description
Dependent variable	LnGRP	Natural logarithmic value of CBD GRP ($billion)
Independent variables	LnTotemploymt	Natural logarithmic value of CBD total employment size ('0,000 workers)
	LnDailyrail	Natural logarithmic value of daily rail capacity provided to serve CBD ('00,000 passenger trips)
	LnConcentn	Natural logarithmic value of CBD employment concentration ('0,000 workers / km^2)

7.5.1.1 Sample Size

A key concern for regression analysis is the size of the dataset which must be large enough so that the regression results are reliable (Green, 1991, Kelly and Maxwell, 2003). According to Hair et al., (2006, page 197), for multiple regressions, the minimum ratio of observations to independent variables is 5 to 1, but the preferred ratio is 15 or 20 to 1. They highlighted that this ratio should increase when stepwise regression is used.

Based on this guideline from Hair et al. (2006), a minimum sample of 15 cities is needed for this assessment since there are 3 independent variables. This research selected a sample size of 20 cities in view of the stepwise regression employed in this analysis. The sample size of 20 is also to meet the sample size requirement for the subsequent simple regression - Hair et al. (2006, page 197) indicated that a sample size of 20 is effective for simple linear regression.

7.5.2 Multiple Regression

7.5.2.1 Method of Regression

According to Field (2009, page 213), the stepwise regression approach is good for exploratory model building. A minimum least-squares linear regression technique was adopted to model the relationship between the dependent variable (i.e. LnGRP) and the independent variables (i.e. LnTotemploymt, LnConcentn and LnDailyrail). Two methods of stepwise regression approach are available – the forward and backward stepwise method. This research adopted the backward stepwise selection method to select the significant variables. The backward method is preferred to the forward method as the latter runs a higher risk of making a Type II error i.e. missing a predictor that does in fact predict the outcome (Field, 2009, page 213).

Based on the backward stepwise approach, the model does the selection by including all the variables at the start of the analysis and the insignificant variables are then eliminated from the model through an iterative process. When no more variables can be eliminated, the analysis is completed. Results of the regression are reported next.

7.5.2.2 Results

The main results of the backward stepwise regression modelling with CBD GRP as the dependent variable are shown in Table 7.4(a) to (c). The adjusted R^2 and F-ratio were examined to assess the overall statistical fit of the model. The final model has an adjusted R^2 of .939 - from Table 7.4(a) - which indicates that the model is a good fit of the sample. The F-ratio of the final model is also very high (291.034) and significant ($p < .001$). This indicates that the difference between the model and observed data is small which reaffirms that the model is performing well. The good statistical fit of the model is also evident from the small difference (of .003 or 0.3%) between the adjusted R^2 of .939 and the R^2 value of .942. The 0.3% shrinkage means that if the model were derived from the population rather than a sample, it would account for approximately 0.3% less variance in the outcome.

To ascertain how well the model represents the wider population, a cross validation of the model was carried out using the Stein's formula as shown in Equation 7.11.

$$Adjusted\ \ R^2 = 1 - [(\frac{n-1}{n-k-1})(\frac{n-2}{n-k-2})(\frac{n+1}{n})](1-R^2) \qquad \text{(Equation 7.11)}$$

where

- R^2 is the unadjusted value
- n is the sample size
- k is the number of independent variables.

Based on this equation, the adjusted R^2 is computed as follows.

$$Adjusted\ \ R^2 = 1 - [(\frac{20-1}{20-3-1})(\frac{20-2}{20-3-2})(\frac{20+1}{20})](1-0.942)$$

$$= 1 - [(1.186)(1.200)(1.050)](0.058)$$

$$= 1 - 0.087$$

$$= 0.913$$

This value is close to the observed value of R^2 (.942) which suggests that the cross validity of the model is reasonably good.

As shown in the last column of Table 7.4 (a), the Durbin-Watson statistic value is 1.833. This is close to 2 which indicates that the errors in the regression are independent. This is important because if the errors in the regression model are correlated, there may be results that appear to be statistically significant but are not.

Table 7.4: Results of stepwise regression with LnGRP as the dependent variable - output from SPSS

Table 7.4 (a) Model Summary[d]

Model	R	R^2	Adjusted R^2	F	Sig.	Durbin-Watson
1	.975[a]	.950	.941	101.610	.000[a]	1.833
2	.973[b]	.946	.940	149.320	.000[b]	
3	.970[c]	.942	.939	291.034	.000[c]	

a. Predictors: (Constant), LnConcentn, LnTotEmploymt, LnDailyrail

b. Predictors: (Constant), LnConcentn, LnTotEmploymt

c. Predictors: (Constant), LnTotEmploymt

d. Dependent Variable: LnGRP

Table 7.4 (b): Coefficients

Model		Unstandized Coefficients		t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.585	.307	-1.906	.075	-1.235	.066		
	LnDailyrail	.097	.086	1.131	.275	-.085	.279	.226	4.420
	LnTotEmploymt	1.026	.125	8.207	.000	.761	1.290	.264	3.782
	LnConcentn	-.229	.148	-1.549	.141	-.542	.084	.735	1.361
2	(Constant)	-.799	.243	-3.283	.004	-1.313	-.286		
	LnTotEmploymt	1.144	.069	16.640	.000	.999	1.289	.888	1.126
	LnConcentn	-.159	.135	-1.177	.256	-.445	.126	.888	1.126
3	(Constant)	-.941	.214	-4.408	.000	-1.390	-.493		
	LnTotEmploymt	1.117	.065	17.060	.000	.979	1.254	1.000	1.000

Table 7.4 (c): Correlations

		LnTotEmploymt	LnGRP	LnDailyrail	LnConcentn
LnTotEmploymt	Pearson Correlation	1	.970**	.852**	.335
	Sig. (2-tailed)		.000	.000	.149
LnGRP	Pearson Correlation	.970**	1	.843**	.262
	Sig. (2-tailed)	.000		.000	.264
LnDailyrail	Pearson Correlation	.852**	.843**	1	.490*
	Sig. (2-tailed)	.000	.000		.028
LnConcentn	Pearson Correlation	.335	.262	.490*	1
	Sig. (2-tailed)	.149	.264	.028	

** correlation is significant at the 0.01 level (2-tailed)

* correlation is significant at the 0.05 level (2-tailed)

The regression modelling results suggest that the LnTotEmploymt is the only statistically significant independent variable in the model at $p<.05$. This means that the LnTotEmploymt variable makes a significant contribution to predicting the outcome of the LnGRP variable. Both LnConcentn and LnDailyrail are not included in the final model due to lack of statistical significance.

The final model has an adjusted R^2 of .939 which indicates that total CBD employment is able to explain about 94% of the variation in the CBD's GRP value. Based on the results reported in Table 7.4(b), the final model is represented as follows.

Ln(CBD GRP) = 1.117 Ln(CBD Employment) – 0.941 (Equation 7.12)

The coefficient value of 1.117 for CBD employment in the final model indicates an increasing returns to scale function which may suggest the presence of agglomeration effects. This value of 1.117 suggests that increasing the CBD employment size by 1% is likely to increase the CBD's productivity by 1.117%. The relative additional increase of 0.117% essentially translates to a productivity elasticity of 0.12 which is a very high value compared to those found in previous research (for example, Ciccone (2002) found an elasticity value of 0.045 between labour productivity and employment concentration for several European countries while Venables and Rice (2004) estimated a productivity elasticity value of 0.05 based on UK data - see Section 2.6.4 for more examples). The 0.12 elasticity suggests that doubling the employment size may increase the CBD's productivity by a substantial 8.5% ($=2^{0.12}-1$)[8]. The association between employment size and productivity of CBDs are discussed further in Section 7.5.3.1.

[8] Various studies (e.g. Graham and Van Dender, 2009, Rosenthal and Strange, 2004) have suggested this method of estimation to provide a discrete approximation of the productivity gains due to large changes in the economic mass. See footnote 12 of Chapter 2 for more information.

Table 7.4 (c) reports the correlations between the various variables. A correlation of above .80 indicates that the two variables are highly correlated (Field, 2009, page 224). The results show that LnDailyrail is highly correlated to LnTotEmploymt with a correlation of .85. This suggests that the results of the earlier regression model which shows the daily rail provision to be statistically insignificant could be due to a multicollinearity effect between the LnDailyrail and LnTotEmploymt variables as reported in the collinearity statistics in Model 1 reported in Table 7.4 (c). Their relatively higher variation inflation factor (VIF) and their tolerance statistic which are close to .2 are indications of collinearity effects. This suggests that daily rail capacity provision could also be a reasonable predictor of GRP in the absence of total employment.

The regression results also suggest that employment concentration is not a significant variable in predicting the productivity of CBDs since $p>.05$. This validates the earlier hypothesis that employment concentration is a less significant predictor of its GRP.

7.5.3 Elasticity Evaluation

The following section examines the individual relationship between CBD employment size, GRP and its daily rail provision in the following order.

- **Section 7.5.3.1 -** **CBD Employment Size and GRP** examines the relationship between the GRP of CBDs and their employment size.
- **Section 7.5.3.2 -** **CBD Employment Size and Daily Rail Capacity Provision** explores how CBD employment relates to daily urban rail capacity provision.
- **Section 7.5.3.3 -** **CBD GRP and Daily Rail Capacity Provision** investigates the relationship between the GRP of CBDs and their daily rail capacity provision.

7.5.3.1 CBD Employment Size and GRP

1. Elasticity Estimation

The GRP of a CBD is highly correlated to its employment size as shown in the results presented in Table 7.4(c). The results suggest that the two variables are highly correlated at a .01 significance level (2-tailed) with a Pearson correlation coefficient of .97.

Figure 7.4 shows a plot of the total CBD employment against the total CBD GRP for the 20 cities. The X-axis represents the total CBD employment while the Y-axis represents the natural logarithmic transformed value of the CBD GRP. A natural logarithmic functional form trendline is fitted to the scatter plot and as expected, the resultant model is similar to the final model obtained in the multi-regression (represented by Equation 7.12).

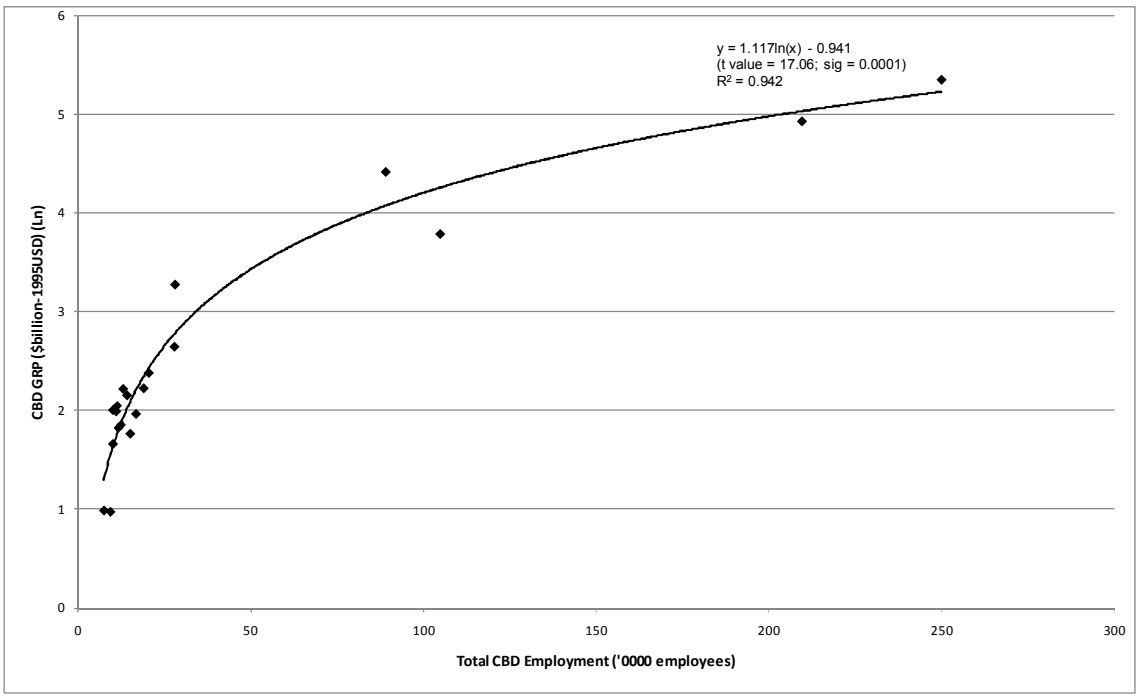


Figure 7.4: Plot of total CBD employment against CBD GRP for the 20 cities

As explained earlier, the coefficient value of 1.117 shown in Figure 7.4 represents the elasticity between total CBD employment and GRP. The statistical assessment results suggest that the LnTotEmploymt variable is a significant predictor of the LnGRP variable at $p<.05$. The coefficient value of 1.117 suggests a productivity elasticity of 0.12[9] for CBDs. This is higher than the range of 0.04 – 0.11 found by Rosenthal and Strange (2004) for cities in general, which supports the proposition in Section 2.6.4 that CBDs enjoy higher productivity gains from agglomeration compared to cities as a whole given their larger employment sizes and knowledge-based economies.

2. Benchmark Implications for Melbourne CBD

Using the productivity elasticity value of 0.12, it is estimated that a 10% rail capacity constraint which is associated with a short term employment suppression impact of 0.69% - 1.07%, may potentially result in a productivity loss that will cost Melbourne CBD 0.08% - 0.13% of its GRP. This range has been used to benchmark the economic values of the productivity impacts estimated via the economic modelling approach in Chapter 8.

3. Sensitivity Tests

Ciccone (2002) suggests that the European region generally has a lower productivity impact from agglomeration compared to American cities. A series of sensitivity tests was therefore undertaken to assess how the coefficient elasticity value of 1.117 derived in Figure 7.4 will fluctuate with changes made to the sample of cities examined. The sensitivity test results indicate that a coefficient value as high as 1.222 could be achieved if the sample included less European cities (see Figure 7.5). This supports the findings of Ciccone (2002).

[9] It is to be highlighted that this research refers to the elasticity between productivity gains and employment concentration as productivity elasticity. This elasticity is not the same as the agglomeration elasticity estimated by Graham (2005, 2006b) which refers to the elasticity between productivity gains and the change of accessibility between workers and firms – he terms the latter as the effective employment density – see footnote 10 for more details.

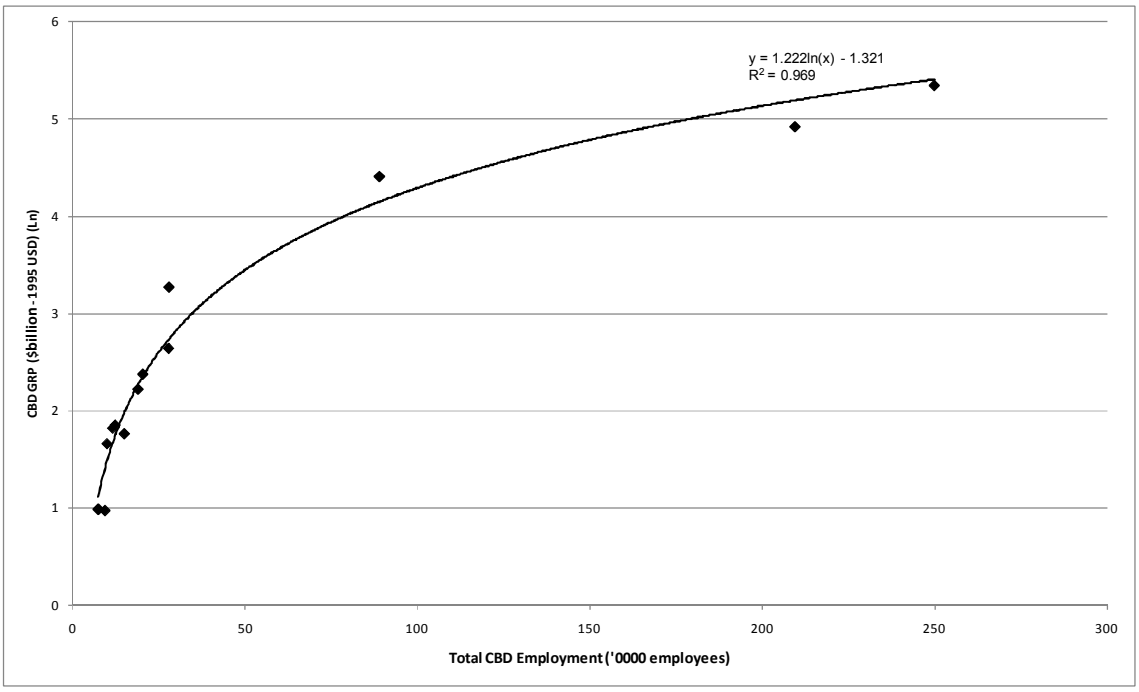


Figure 7.5: Sensitivity analysis - total CBD employment against CBD GRP

The coefficient value of 1.222 also suggests that the doubling of CBD employment size could possibly result in an additional GRP gain of 17% ($=2^{0.22}-1$). This is consistent with the findings of Graham (2007a, 2006b) who concluded that the doubling of city size would bring about a 24% and 22% increase in the respective output of the Financial and Business sectors – these industries featured prominently in the CBD. In addition, using the agglomeration elasticities[10] derived by Graham (2006b) and the CBD employment from the Census of Land Use and Employment (City of Melbourne, 2006), Section 2.6.4 estimated a weighted agglomeration elasticity of 0.216 for Melbourne CBD. The weighted elasticity of 0.216 elasticity essentially means that doubling the employment densities[11] of Melbourne CBD could potentially raise its productivity by an additional 21.6%.

[10] Graham (2006a, 2006b) defined agglomeration elasticities as the elasticity between the productivity of a region with respect to the effective employment density. The latter is an agglomeration metric that measures the accessibility of workers to firms adopted by Graham (2006a, 2006b) to model agglomeration economies.

[11] As explained in footnote 10, the effective employment density does not refer to the number of workers per unit area. The total number or workers per unit area is term as the employment concentration in this research so as to differentiate against employment density.

7.5.3.2 CBD Employment Size and Rail Capacity Provision

1. Elasticity Estimation

As shown in Table 7.4(c), the correlation between total CBD employment and daily rail capacity provision is significant - the two variables are highly correlated at a .01 significance level (2-tailed) with a Pearson correlation coefficient of .85. This is not surprising since only rail cities are selected for analysis.

Table 7.5 reports the linear regression modelling results where the dependent variable is the total CBD employment (i.e. LnTotEmploymt) and the independent variable is the daily rail capacity provided to serve the CBD (i.e. LnDailyrail).

Table 7.5: Results of linear regression with LnTotEmploymt as dependent variable - Output from SPSS

Table 7.5 (a) Model Summary[b]

Model	R	R^2	Adjusted R^2	F	Sig.	Durbin-Watson
1	.852[a]	.727	.711	47.826	.000[a]	2.348

a. Predictors: (Constant), LnDailyrail

b. Dependent Variable: LnTotEmploymt

Table 7.5 (b): Coefficients

Model		Unstandized Coefficients		t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	1.696	.239	7.102	.000	1.194	2.198		
	LnDailyrail	.542	.078	6.916	.000	.377	.706	1.000	1.000

The adjusted R^2 and F-ratio were examined to assess the overall statistical fit of the model. As shown in Table 7.5(a), the final model has an adjusted R^2 of .711 which indicates that the model is a reasonably good fit of the sample. The F-ratio of the final model is also high (47.826) and significant (p <.001). This indicates that the model is performing reasonably well. The reasonably good statistical fit of the model is also evident from the small shrinkage (of .016 or 1.6%) between the adjusted R^2 of .711 and the R^2 value of .727.

As shown in Table 7.5(a), the Durbin-Watson statistic value of 2.348 is close to 2 which suggest that the errors in the regression are independent.

The model achieved an adjusted R^2 value of .71 which suggests that daily rail capacity provision accounts for about 71% in the variability of the CBD's total employment. Results of the regression analysis suggest that a 0.54% increase in total CBD employment is possibly associated with a 1% increase in daily rail capacity provision – as shown by the unstandardised coefficient value of 0.542[12] in Table 7.5(b). The results suggest that this correlation is significant at $p<.05$.

2. Benchmark Implications for Melbourne CBD

It was established in Chapter 4 (Figure 4.8) that a total of 173 train services presently serve Melbourne CBD during the AM peak of a typical weekday. This is represents about 19.7% of the total 879 train services which serve Melbourne CBD each day. Therefore a 10% rail capacity constraint in the AM peak hour would essentially translate to 1.97% constraint in daily rail capacity provision for the CBD, ceteris paribus.

The regression results above suggest that a 10% constraint in the AM peak hour rail capacity constraint is potentially associated with a CBD employment suppression impact of 1.06% (=1.97%*0.54%). This is close to the upper limit of the short term employment suppression impact of 0.69% - 1.07% estimated in Section 5.6.4 using the outputs from the transport model. It is also within the range of -0.97% ± 0.13% (at 95% confidence interval) established in the survey – see Figure 7.6. This supports the earlier proposition that the CBD employment suppression impacts estimated in Chapters 5 and 6 are plausible.

[12] Pallant (2005) explained that the unstandardised coefficients are to be used in constructing a regression equation. This coefficient of 0.542 therefore represents the elasticity between the dependent and independent variables.

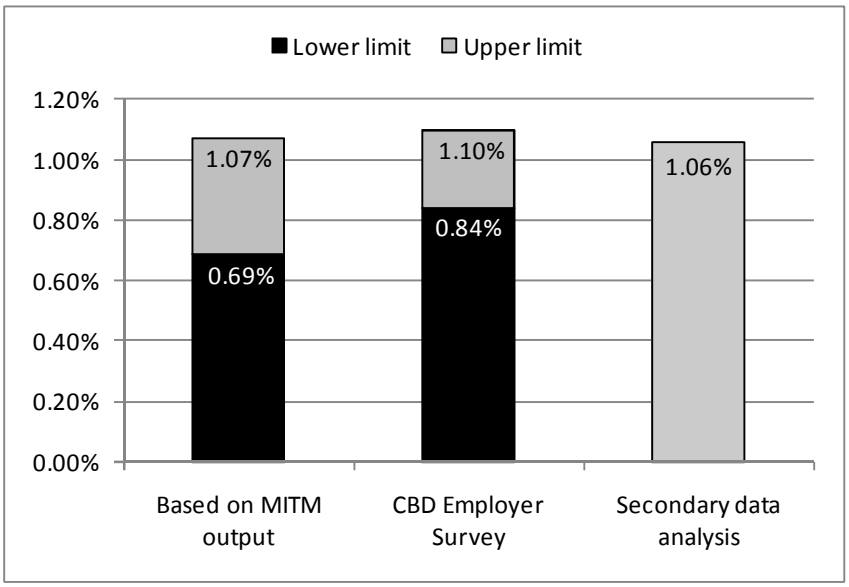


Figure 7.6: Employment suppression impact associated with a 10% rail capacity constraint (AM peak) estimated via different approaches – short term

The higher employment suppression impact value estimated in this instance could be due to the composition of the sample - the secondary data analysis was based on a sample of international cities where most of them had a CBD employment larger than that of Melbourne CBD in 1995; the larger CBD employment essentially yielded a larger employment suppression impact associated with a 10% rail capacity constraint in the AM peak.

7.5.3.3 CBD GRP and Daily Rail Capacity Provision

Table 7.4 (c) shows that GRP of a CBD is highly correlated with its amount rail capacity provision - the two variables are highly correlated at a .01 significance level (2-tailed) with a Pearson correlation coefficient of .84. Statistical analysis was also conducted to investigate the relationship between the CBD's GRP and the amount of daily rail capacity provided to serve the CBD. The regression model is set up with LnGRP as the dependent variable and LnDailyrail as the independent variable. The results are reported in Table 7.6.

Table 7.6: Results of linear regression with LnGRP as dependent variable - Output from SPSS

Table 7.6 (a) Model Summary[b]

Model	R	R^2	Adjusted R^2	F	Sig.	Durbin-Watson
1	.843[a]	.710	.694	44.148	.000[a]	1.975

a. Predictors: (Constant), LnDailyrail

b. Dependent Variable: LnGRP

Table 7.6 (b): Coefficients

Model		Unstandized Coefficients		t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.923	.283	3.261	.004	.329	1.517		
	LnDailyrail	.616	.093	6.644	.000	.421	.811	1.000	1.000

The adjusted R^2 and F-ratio were again examined to assess the overall statistical fit of the model. The final model has an adjusted R^2 of .694 - from Table 7.6(a). The F-ratio of the final model is also high (44.148) and significant (p <.001). Both the adjusted R^2 and F-ratio suggest that the model is a reasonably good fit of the sample. The small difference (of .016 or 1.6%) between the adjusted R^2 of .694 and the R^2 value of .710s also indicates that the model is a reasonably good statistical fit.

As shown in Table 7.6(a), the Durbin-Watson statistic value is 1.975. This is close to 2 which indicate that the errors in the regression are not correlated.

The Univariate Analysis of Variance yielded an adjusted R^2 value of .69 (Table 7.6(a)) which suggests that rail capacity provision accounts for about 69% in the variability of the CBD's GRP. Results shown on Table 7.6(b) suggest that a 1% increase in daily rail capacity provision is possibly associated with a 0.61% increase in the CBD's GRP. The results suggest that this relationship is significant at $p<.05$.

The 0.61% increase in the CBD's GRP associated with a 1% increase in daily rail capacity provision is close to the upper limit of 0.70% GRP impact estimated in earlier studies reviewed in Chapter 2 (refer to Section 2.7). However, as highlighted in Chapter Two, this productivity impact may not be totally attributable to agglomeration effects and hence it cannot be directly compared against the 0.08% – 0.13% GRP impact range estimated in Section 7.5.3.1. Nonetheless, the significant correlation between the two variables does support the earlier proposition that agglomeration benefits associated with transport investments are valid and could be significant.

7.6 Critique of Data Set

Gomez-Ibanez (1991) lauded the UITP (2001) Millennium Cities Database as a "formidable accomplishment" while Van de Coevering and Schwanen (2006) defined the work as "groundbreaking and influential". While this database marks a remarkable step forward in determining the economics of mobility in cities in the world (Vivier, 2001) and has made a very important contribution to the understanding of the intriguing relationships between urban form and travel patterns (Coevering and Schwanen, 2006), it is "obviously not perfect" (Vivier, 2001). Several studies have criticised the database, principally on the following two aspects.

1. Omission of variables -

   Several authors (such as Karathodorou et al., 2010, Coevering and Schwanen, 2006, Mindali et al., 2004) have highlighted the omission of other variables known to affect mobility and commuting patterns, such as socio-economic variables (other than the Gross Regional Product), or housing and development history-related factors (Coevering and Schwanen, 2006) as well as highway user charges and taxes, public transport fares and operating subsidies (Gomez-Ibanez, 1991). Karathodorou et al. (2010) stressed that the omitted variables may also introduce some level of bias in regression modelling.

2. Inconsistencies in variable definitions and data collection procedures –

   Another possible drawback of the "Millennium Cities Database" is that inconsistencies may exist in the data collection procedures and definitions of the variables (Karathodorou et al., 2010). Vivier (2001) reported that the difficulties in maintaining a consistent data collection procedure arise primarily due to a lack of statistics (chiefly in developing countries) or lack of enthusiasm from some country's statistical agency. Gomez-Ibanez (1991) and more recently, Mees (2009) highlighted that one of the key area of inconsistencies is the definition of the urban boundary. This limitation was also acknowledged by the team that compiled the database who highlighted that "the first difficulty faced involves setting the boundaries of conurbations (Vivier, 2001, page 5).

In line with this research's focus, Vivier (2001) highlighted the difficulties in collecting data related to the use of public transport commuter rail services. In particular, she cited difficulties in separating commuter services for the metropolitan area from inter-urban rail services as one of the key challenges. For the purpose of this exercise, data on the space-time context of rail services (such as average rail trip length, operation frequency etc) is required. However, such information is not available in UITP (2001). Therefore, this research complemented the rail services data from the Millennium Cities database with relevant information from the various rail operators and transport authorities. Further details of this are reported in Section 7.3 and Appendix D of this thesis.

Apart from the weaknesses highlighted above, this research also identified some other drawbacks with the UITP (2001) database. This research primarily made use of data on CBD employment, GRP and the use of commuter rail services from UITP (2001). The data were collected about 15 years ago (1995) and may not offer the most up-to-date information for research. In particular, the then developing countries (such as Singapore) are likely to have made significant progress in terms of their economic and infrastructure developments over the last 1-2 decades. While it would be ideal to conduct this analysis using updated information, Vivier (2010) has made it clear that the UITP's (2001) database remains the most comprehensive and reliable data compilation produced to date[13]. There is no later version of the databank available.

Souche (2010) highlighted that some of the GRP data collected in UITP (2001) appears questionable. She cited the example of the 1995 GRP per capita for Paris ($41,000) being twice that of London ($22,300). Souche (2010) explained that these distortions were caused by bias in the pricing levels and variations in exchange rates and could be eliminated if the GRP figures had been converted based on purchasing power parity (PPP) instead.

[13] Obtained via personal communication.

However, Kenworthy and Laube (1999, page 699) defended their rationale for converting the GRP of various cities into US dollars based on nominal exchange rates as there are methodological problems in using the PPP approach which is of "particular relevance in the area of transportation and urban form". They explained that the PPP approach, which involves a selection of a range of goods, is not a good approach for converting GRP in the UITP (2001) database given that there is a value judgement involved in the selection of goods. They highlighted that the inclusion of a car and house in the basket of representative choices of goods may artificially undervalue the currency of countries where there is a high tax on cars and premium on housing.

The issue of value judgement in the PPP approach raised by Kenworthy and Laube is evident in the different PPP exchange rates provided by different sources. For example, the 1995 PPP exchange rates provided by the Organisation for Economic Co-operation and Development (OECD) (2010) is different from those provided by the International Monetary Fund (IMF) (2004) – e.g. the 1995 PPP exchange rate from OECD (2001) was US$1: ¥178.460 but the IMF (2004) rate was US$1: ¥174.605. To test the validity of the PPP versus the nominal exchange rate approach, this research reconstructed the GRP data in UITP (2001) using PPP and nominal exchange rates from the International Monetary Fund (2010, 2004)[14] for sensitivity test purposes.

The statistical analysis based on the reconstructed GRP data shows the same general trend as those reported in Section 7.4.2.2. For example, the regression analysis between CBD total employment (independent variable) and GRP (dependent variable) using the PPP results estimated a coefficient range of 1.062 – 1.105 which suggests a productivity elasticity range of 0.62 – 0.11. This is noted to be about half the productivity range of 0.11 – 0.22 reported in Section 7.4.2.2 which was based on the nominal exchange rates. Nonetheless, the sensitivity results still suggest that the productivity impact of agglomeration may be significant.

[14] The nominal exchange rates were used to convert the GRP of each CBD into their respective currency. The PPP exchange rates were then applied to convert them to US dollar equivalents. The IMF source was chosen as it contains the PPP rates for all countries in the sample. Other sources, such as OECD (2010), may miss out on the PPP exchange rates of some countries.

7.7 Summary

This chapter presents the findings of the secondary data analysis which was carried out to investigate how CBD employment and productivity relate to its urban rail provision. The analysis was conducted using data on 20 major international and Australian cities from UITP's (2001) Millennium Cities Database. The sample size of 20 was adopted based on the minimum ratio of observations to independent variables of 5 to 1 stipulated in Hair et al., (2006, page 197).

A comparative assessment of the cities was conducted to hypothesise the relationship between the employment size, GRP and rail capacity provision of CBD. From the assessment, it was hypothesised that employment concentration is a less significant predictor of a CBD's GRP and urban rail provision compared to total employment size. A second hypothesis that CBDs with larger employment size are associated with higher level of urban rail provision and higher GRP gains, was also formed arising from the comparative assessment. The validities of these hypotheses were statistically tested using the SPSS software.

A backward stepwise regression of this 20 CBD sample with the GRP as dependent variable and total employment, employment concentration and daily rail capacity provision as independent variables was carried out. The statistical analysis derived a final model where the GRP of a CBD is only significantly correlated to its total employment size. The t-statistic significance of better than .05 for the employment concentration variable validates the hypothesis that CBD employment concentration is a less significant predictor of GRP and rail capacity provision than total employment.

The daily rail provision was also assessed to be not a significant variable due to the presence of multicollinearity effects with the total CBD employment. The final model yielded a coefficient of 1.117 for the independent variable which signals the presence of agglomeration effects since it suggests that a doubling of CBD employment could result in a relative GRP gain of 11.7%.

The coefficient value of 1.117 between CBD employment and GRP suggests a productivity elasticity of 0.12. This is noted to be higher than the 0.04 – 0.11 range identified by previous studies. This supports the proposition that CBDs enjoy higher productivity gains from agglomeration compared to cities as a whole given their larger employment sizes and knowledge-based economies. Using this productivity elasticity value, this research estimated that a 10% rail capacity constraint is associated with a short term productivity impact amounting to 0.08% - 0.13% of the CBD's GRP. This range has been used to benchmark the economic values of the productivity impacts estimated via the CGE modelling approach in Chapter 8.

Sensitivity analysis using the same regression model also shows that a coefficient value as high as 1.222 could be achieved if the sample included less European cities. The 1.222 coefficient which suggests that the doubling of CBD employment size could result in an additional GRP gain of about 17%, is consistent with the recent work of Graham (2007a, 2006b).

Further statistical assessment indicates that a 10% constraint in the AM peak hour rail capacity constraint is potentially associated with a CBD employment suppression impact of 1.06%. This is within the short term employment suppression impact of 0.69% - 1.07% estimated in Chapter 5 and the surveyed employment impact of -0.97% in Chapter 6. This suggests that the CBD employment suppression impacts estimated using MITM's outputs and that obtained from the CBD employer survey are plausible.

CHAPTER 8

TERM Modelling

8.1 Introduction

This chapter reports on simulations conducted with a multiregional Computable General Equilibrium (CGE) model, TERM (The Enormous Regional Model[1]). TERM is a general purpose CGE model which can be used to analyse a wide range of economic issues regarding Australia's regional economies. In this research, an aggregated version of the TERM model of Australia is used to explore how the agglomeration effects associated with urban rail might impact the economy of Melbourne Central Business District (CBD) and to test whether there might be any flow-on inter-regional effects. The use of TERM to estimate such agglomeration dis-benefits represents one of the approaches used by this research to estimate the economic value of the change in proximity between CBD firms and workers associated with an urban rail capacity constraint[2]. Figure 8.1 shows how this CGE modelling work (shown boxed in red) fits into the overall research framework. Modifications are introduced to the TERM model to facilitate the particular transport application reported here.

TERM belongs to the suite of ORANI-style CGE models developed by the Centre of Policy Studies (CoPS)[3], Monash University. TERM was constructed in early 2000's to meet the demand for a model dealing with small (sub-state) regions (Horridge et al., 2005). TERM shares features with CoPS' other models; in particular its national ORANI (Dixon et al., 1982) and MONASH (Dixon and Rimmer, 2002) models and its multiregional (state-level) model, the Monash Multiregional Forecasting model (MMRF)[4].

---

[1] This is the name given to the model by its creators at the Centre of Policy Studies, Monash University in order to highlight its capacity to handle many economic agents and many regions simultaneously (Horridge et al., 2005).

[2] As mentioned in the research methodology (Chapter 3), this research measures the agglomeration effects in urban rail using 2 measures. The change in proximity between CBD firms and workers is the 2nd measure. The other measure is the potential employment suppression impact estimated in the earlier chapters.

[3] CoPS is a leading world research group in the construction and application of CGE models.

[4] MMRF regions are Australia's 6 states and 2 territories.

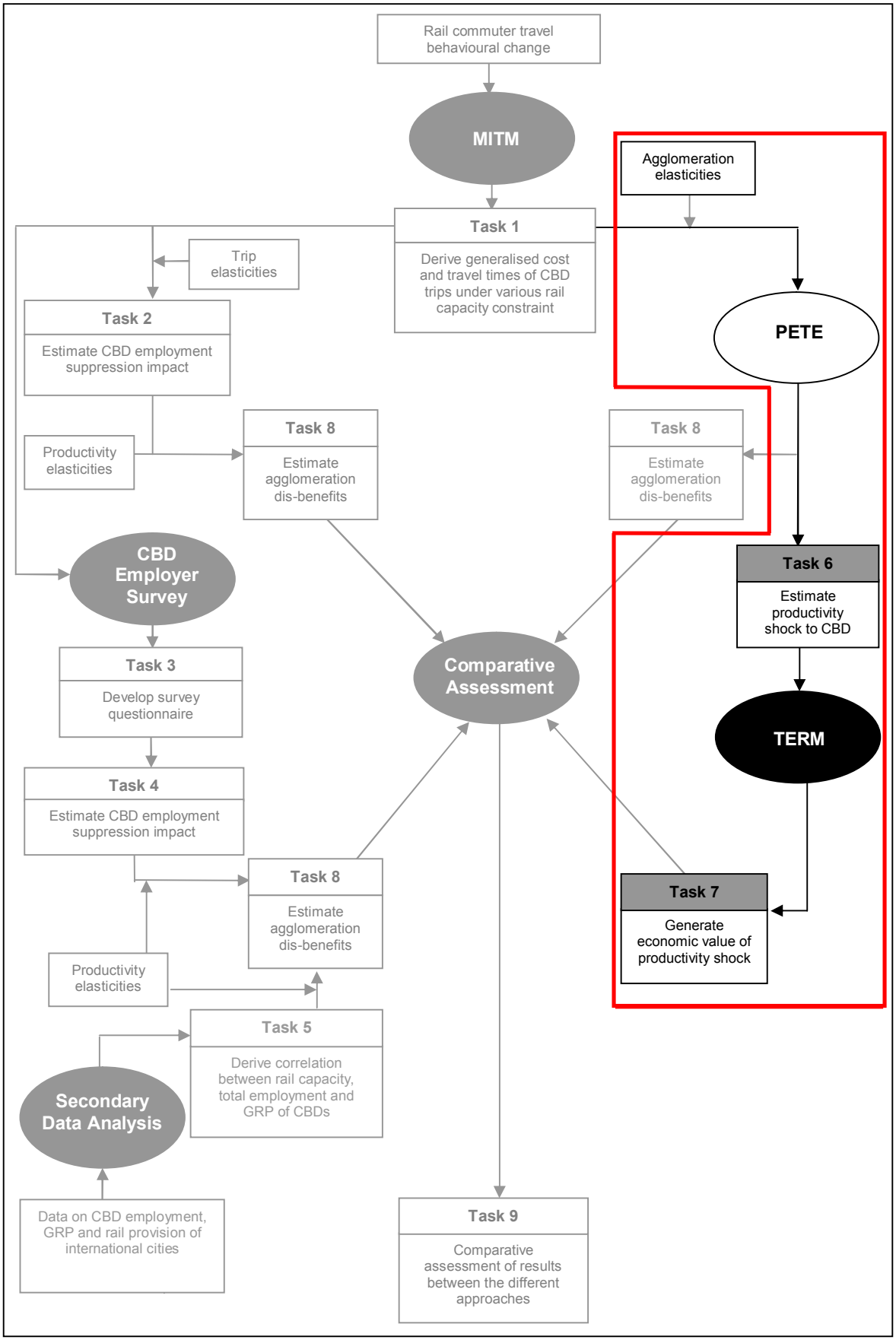


Figure 8.1: Research focus of Chapter Eight

The ORANI-style CGE models, in particular TERM, provide a valuable platform for exploring agglomeration economies in urban rail for the following reasons.

1. The full documentation of the progressive development of the various ORANI-style models is publicly available via peer reviewed journals and reports (for example, the "Labour market models and their use in projecting vocational education and training requirements" report by Burns and Shanahan (2000) where they did a critique of various CGE models). This makes it possible for researchers to replicate the results derived from the model - Burns and Shanahan (2000, page 18) emphasised this as "an essential requirement of the international modelling community".

2. The extensive use of CoPS' suite of CGE models for policy analysis in Australia (since 1975) and many countries (such as the USA, China, Japan, Denmark and Ireland) provides credibility for the ORANI-style models (Dixon and Rimmer, 2010). In addition, the constant exposure of CoPS' CGE models at peer reviewed academic conferences and journals ensure their rigour against overlooking potential improvements in research strategy (Dixon et al., 2002a).

3. This research's CGE application requires some regional disaggregation of the Melbourne metropolitan area. TERM was built with the capability to model economic behaviour in relatively finely disaggregated sub-state regions (Wittwer and Horridge, 2010). In addition, TERM's database[5] can be collapsed and expanded to appropriate dimensions for particular applications (Horridge et al., 2005) via database programs. These features made TERM the most attractive and appropriate model in the ORANI suite for this research's application.

[5] TERM is usually specified for Australia's 55 Statistical Divisions (SDs). These SDs (and sectors) can be collapsed or expanded to appropriate dimensions with the use of database programs.

Figure 8.2 presents an overview of the TERM modelling framework in this research. The modelling approach developed by this research to simulate agglomeration economies in urban rail involves the application of productivity shocks[6] on TERM. A series of productivity shocks associated with a 10% rail capacity constraint was first derived (in Section 8.5) based on to the PETE[7] method which refers to the approach that the UK and New Zealand adopts to estimate agglomeration benefits. Outputs from the Melbourne Multi-modal Integrated Transport Model (MITM) and agglomeration elasticities from secondary research were used as inputs to estimate the productivity shocks.

The productivity shocks were then imposed on the TERM model to estimate their impact to Melbourne CBD's economy – see Figure 8.2. The outputs from TERM were compared against the agglomeration dis-benefits estimated using PETE and other approaches (based on the employment suppression impact measure) to assess the robustness and variability of alternative methods. The agglomeration dis-benefits estimated based on the various approaches are reported in Chapter 9 and the comparative assessment of their results is presented in Chapter 10.

This chapter is organised in the following order.

- **Section 8.2 -** **The TERM Model** outlines TERM's database and theoretical structure, its simulation process and outcome.
- **Section 8.3 -** **Modifications to TERM** highlight alternations made by this research to the current TERM model to facilitate this research's application.
- **Section 8.4 -** **TERM Modelling Approach** presents the experimental work that was carried out to explore the most reasonable way to simulate agglomeration effects in TERM.
- **Section 8.5 -** **Estimation of Productivity Shocks** derives the productivity shocks associated with a 10% rail capacity constraint using the PETE method.
- **Section 8.6 -** **TERM Output** reports the CGE modelling results.
- **Section 8.7 -** **Summary** concludes the chapter.

[6] In CGE terminology, the process of inputting any impact into the economic model so as to simulate its effect on the economy is known as a "shock" (Dixon et al., 2002a).

[7] This research refers to this method as PETE since it essentially measures the **P**roximity between **E**mployees **T**o **E**mployers.

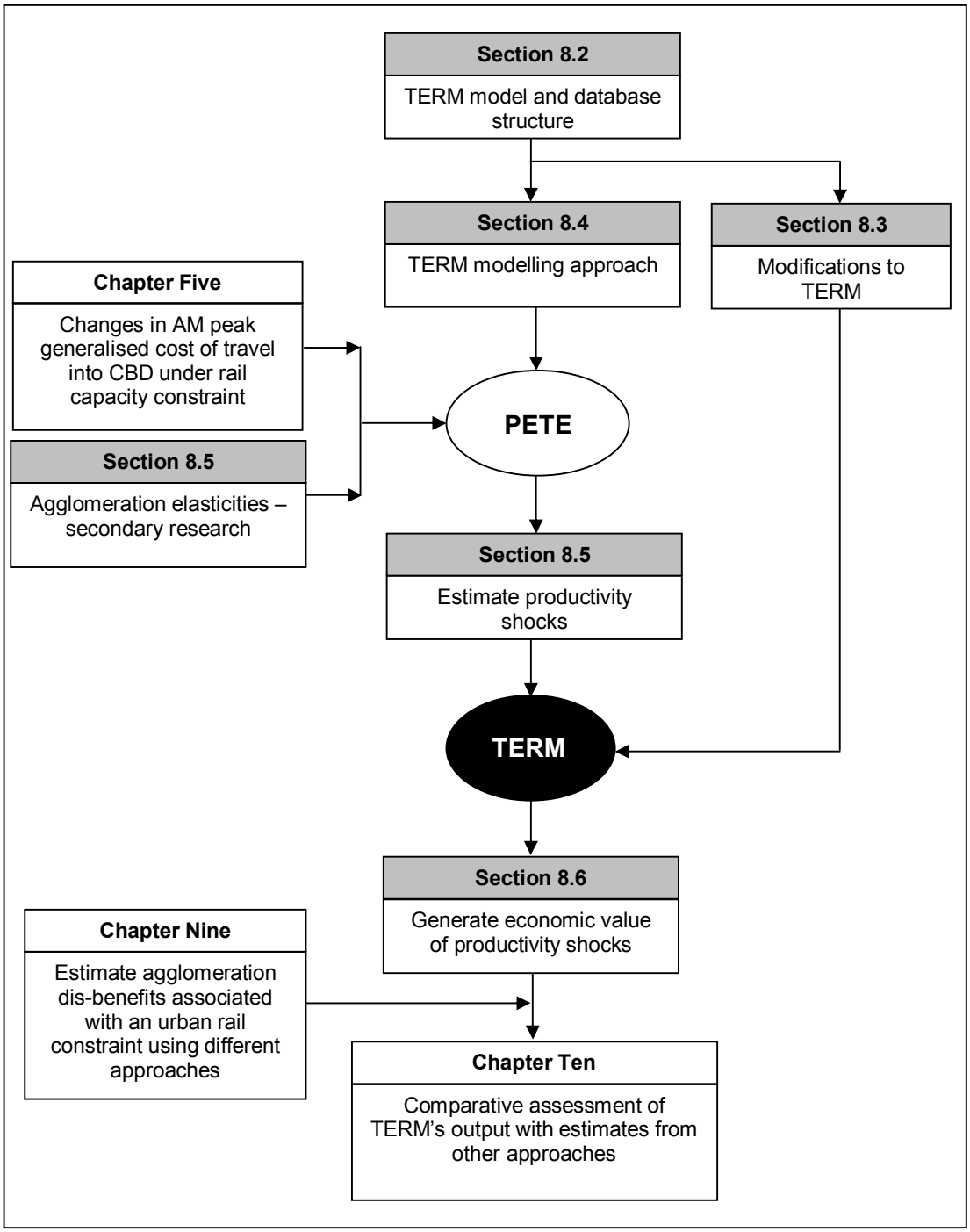


Figure 8.2: Overview of the TERM modelling framework

8.2 The TERM Model

A CGE model is essentially a system of simultaneous equations, which defines the various economic agents and their behaviour, the conditions that bring the different markets into equilibrium, and the region's macroeconomic characteristics (such as balance of payments, investment and savings as well as Government budget). The model makes use of a matrix database that shows the flow of goods and services among the various industrial sectors and economic agents.

CGE models, however, differ in their assumptions about each economic agent's behaviour, their level of sectoral disaggregation and details in their representation of different dimensions of a nation or region's economy. CGE models can be comparative-static or recursive dynamic. A comparative-static model is solved for a single-period equilibrium which can be either the short or long term. A recursive dynamic model, on the other hand, is solved as a sequence of equilibria where the solutions for the model's variables are updated at the end of each period based on assumptions of the current behaviour and the solutions from earlier periods (Dixon and Rimmer, 2002).

The version of TERM used in this research is operated in the comparative-static mode. Given the size of this large "bottom-up"[8] multiregional ORANI-style CGE model, it is not practical to provide a full description of TERM's database and theoretical structure in this thesis. Hence, only the salient features of the TERM model are outlined here. The detailed documentation of TERM can be found in Horridge et al. (2005) and Wittwer and Horridge (2010).

This introduction to TERM is presented in the following sequence.

- **Section 8.2.1 - Database Structure** outlines the organisation of the TERM database.
- **Section 8.2.2 - Theoretical Structure** explains the core equations that define the TERM model.
- **Section 8.2.3 - Simulation Process and Outcome** presents an overview of TERM's modelling process and its outputs.

[8] A "bottom-up" model is one where each region is treated as a separate economy and the national results are additions of regional results. This is opposite to a "top-down" model where the regional consequences are estimated from national economic changes (Horridge et al., 2005).

8.2.1 Database Structure

Figure 8.3 is a schematic representation of a multiregional input-output table that would form an ideal database for an ORANI-style multiregional CGE model[9]. The column headings in the main part of the figure (an absorption matrix) identify the following five types of demanders.

1. Domestic producers divided into J industries in R regions.
2. Investors divided into J industries in R regions.
3. R representative households, one in each region.
4. An aggregate foreign purchaser of exports.
5. The federal government and G-1 sub-national governments[10].

For each demander, the entries in their particular column show the values (which is a product of a price and quantity) of each of their purchases. The first row of matrices shows each demander's purchases of commodities by source valued at basic prices[11]. For example, the matrix, BAS1, shows the base-year direct flows of each commodity i from each source *s* to each of JxR regional industries for the purpose of current production. Similarly, BAS2 shows the flows of commodities from each of the R+1 geographical sources to JxR regional industries for the purposes of capital formation. Note that only domestically produced goods are assumed to be exported; therefore BAS4 are zero whenever s is equal to foreign imports.

The second row of matrices, MAR1 to MAR5, provides the values of margin services[12] associated with each of the direct flows in the corresponding BAS1 to BAS5 matrices. For instance, MAR1 shows the value of each of the M margin services supplied by each of the R domestic regions to facilitate the flow of each of i commodities from each of the R+1 sources (domestic regions and foreign imports) to each of the J industries located in each of the R regions.

---

[9] As discussed below, in practice, computing constraints have meant that most multiregional CGE models use a slightly less full representation of all regional input-output linkages.

[10] In the case of a 2-tier federal system, G-1=R.

[11] The basic price of a commodity is the "factory gate" (or port of entry for importers) price, before the addition of sales taxes and the costs of margin services (such as transport, wholesale, retail and insurance) required to deliver the commodity to the purchaser.

[12] In CGE terminology, margins refer to services (e.g. transport, wholesale and retail trade) that must also be purchased in order for goods to reach a customer located in a particular region (Dixon et al. (1982, page 3). See Section 8.2.2.7 for more details.

The next row of matrices, TAX1 to TAX5, similarly show the net sales taxes imposed by each of the *G* government on each of the corresponding BAS1 to BAS5 flows.

		Producers	Investors	Households	Exports	Government
	SIZE	J x R	J x R	R	1	G
Basic Flows	I x S	BAS1	BAS2	BAS3	BAS4	BAS5
Margins	I x S x M x R	MAR1	MAR2	MAR3	MAR4	MAR5
Commodity taxes	I x S x M x R	TAX1	TAX2	TAX3	TAX4	TAX5
Labour	V x S	LABR				
Labour taxes	V x S	LABT				Trade Taxes
Capital	S	CAPR			I	TARF
Capital Taxes	S	CAPT				
Land	S	LNDR			MAKE MATRIX	Regional Industries
Land Taxes	S	LNDT			Regional Commodities	MAKE
Working Capital	S	WCAP				
Production Taxes	G	PTAX				

where I = Number of Commodities
J = Number of Industries
R = Number of Domestic Regions
S = Number of Geographical Sources (R+ Imports)
M = Number of Margin Commodities
G = Number of Governments (R + Federal for two tier of govt.)
V = Number of Occupations

Source: Gwee and Madden (2010)

Figure 8.3: Full dimension multiregional CGE model database

As shown in Figure 8.3, for the producers' column of matrices, there are a further series of matrices which show the various elements of value-added and production taxes. Note that each of the value-added matrices is disaggregated by a source dimension. This is to identify the region of ownership of the factor. For example, LABR shows the after-tax provision of V occupations supplied from *S* regions of residence to J industries located in R regions[13]. The wage-bill to regional industries (or the before-tax income to employees) is equal to the summation of the corresponding cells in LABR and LABT. Capital and land are similarly disaggregated by after-tax returns and tax on capital earnings.

A key strength of TERM is its compact data structure, which allows it to handle the detailed behaviour of numerous economic agents within many regions while still being sufficiently compact that it can be solved on a high-end personal computer. TERM's compact data structure, which gives rise to its computational efficiency (relative to some other detailed bottom-up multi-regional CGE models), is made possible by a number of simplifying assumptions. For example, TERM assumes that all users in a particular region of a particular commodity source their purchases of that commodity from other regions according to common proportions[14]. The model's compactness has allowed the same detailed bottom-up multiregional treatment of economic agents employed in other large-scale regional CGE models to be included in a model with many more regions.

The advantage of TERM's compact database can be seen in comparison with the database illustrated in Figure 8.3. The problem such a fully-specified database as depicted in Figure 8.3 causes can be seen by considering the dimensions of the MAR1 matrix. Recall that this matrix shows the provision of each margin service supplied by each region to facilitate the flow of each commodity from each source (domestic regions and foreign imports) to each industry located in each region. For example, for a 50-sector model with 50 regions and 6 margin commodities, MAR1 would have the dimension of over 1.9 billion cells[15].

---

[13] In general, one would expect the bulk of the value of wages to be in cells where s=r. Where s=R+1, the employees are non-permanent residents.

[14] Thus, for instance, both households and food-products manufacturers in region *r* are assumed to purchase the same proportion of their vegetables from region *t*.

[15] i.e. 50^4 x 51 x 6 = 1912.5 million.

The database shown in Figure 8.3 is essentially that for the FEDERAL model (Madden, 1990), and thus it is easy to see why FEDERAL has normally been employed as a two-region model[16].

Typically, multiregional CGE models like the MMRF handle the size issue by restrictive assumptions on margins (e.g. margins provided only by destination region) and/or sales taxes (e.g. levied by just an aggregation of Federal and State government) (Navqi and Peter, 1996). TERM, however, reduces the sourcing dimension s in the matrices BAS1 through to TAX5 by the simplifying assumption of common regional-sourcing proportions among users at a particular destination; this allows the size of the database to be collapsed to a workable size without having to reduce the number of regions.

In essence, basic flows and margins are aggregated with their dimensions being reduced to the number of commodities (I) times the two sources nationally (i.e. domestic and imports) times the number of destinations (R) for each user (industries, investors, households, etc.). There is a similar reduction in the size of the tax matrices. The data on sourcing from domestic regions by all users in a particular destination is stored in separate matrices, for direct flows and for margins. A supplementary margins matrix records data on domestic margins being supplied by each region on direct flows between all domestic origin and destination pairs. This is sufficient information to recreate the full margin matrix dimensions (under the assumptions that all users in a particular region of a particular commodity source their purchases of that commodity from regions according to common proportions and the distribution of margins across regions for all origin-destination pairs is the same for all commodities)[17].

TERM database framework also provides some extra information with respect to foreign imports that are not shown in Figure 8.3. TERM specifies for foreign imports the domestic regions in which the imports land. Margins are then supplied on transporting imports from the region of entry to the destination region. For a diagrammatic depiction of the TERM database, see Horridge et al. (2005).

---

[16] Restricting the number of regions to 2, while maintaining the same number of industries/commodities and margin commodities, reduces the dimension of MAR1 to 180,000.

[17] Side matrices are not maintained for the tax matrices, with taxes assumed to be levied by the destination region.

The TERM input-output database is estimated from the national input-output table, using a traditional gravity formula, location quotients and port information (Horridge et al., 2005). This is done at a highly disaggregated level. Transport margin values thus contain a distance component.

For the purpose of this research, a 5-region version of TERM was generated, with three of its regions being in Melbourne[18]. In this version of TERM, the Melbourne metropolitan area was disaggregated into three regions (Inner, Middle and Outer). These follow the geographical boundary defined for the corresponding region in the Australian Standard Geographical Classification (ABS, 2009d). In addition, all other Victorian Statistical Divisions (SD) were aggregated into RoV (Rest of Victoria) and all the SDs of the other five states and two territories were also aggregated into a single region, RoA (Rest of Australia) in this version. Melbourne CBD, which is the study area of this research, is incorporated in the Inner Melbourne region[19].

8.2.2 Theoretical Structure

TERM consists of a system of equations to specify each of the following relationships:

- Producers' demands for produced inputs and primary factors
- Producers' supplies of commodities (including margins)
- Demands for inputs to capital formation
- Demands for margins services
- Household demands
- Export demands
- Government demands
- Inventories demands
- The relationship of basic values to production costs and purchasers' prices
- Market-clearing conditions for commodities and primary factors
- Numerous macroeconomics variables and price indices.

  (Wittwer and Horridge, 2010)

[18] We might refer to this version as the TERM (Melbourne) model, although for convenience it is simply referred to as the TERM model in this thesis.

[19] As shown in Figure 4.1, Inner Melbourne region comprises Melbourne, Port Philip and Yarra Local Government Area (LGA) as well as Stonnington (C) – Prahran Statistical Local Area. Melbourne CDB is a subset of Melbourne LGA.

An outline of TERM's theoretical structure is presented next. A more detailed description of TERM's theoretical structure in provided in Appendix E which describes the 51 core equations and 72 key variables that summarises the structure and functioning of the TERM model[20] used in this research.

8.2.2.1 Sourcing Mechanism in TERM

One of the defining features in TERM is its regional sourcing mechanism. In TERM, economic agents decide on the geographical source of their purchases based on relative prices and a nested structure of substitution possibilities. The first decision facing the economic agent is whether to purchase a commodity that is produced in Australia or one that is imported from overseas. If an Australian product is chosen, a second decision must be made as to the particular region the commodity originates from. Table 8.1 presents four generic equations that define this two stage sourcing mechanism for the various economic agents in TERM. Tables 8.2 and 8.3 describe the variables and the model's sets and set elements.

Table 8.1: Generic equations that define the sourcing mechanism in TERM

Equations
Equation 8.1: Quantity demand of commodity *c* from source *s* (either domestic composite or import) by user *u* in region *d* $X_{ud}^{cs} = f(X1_{ud}^{c}, CES[P_{ud}^{cs} / P1_{ud}^{c}]$
Equation 8.2: Average price of domestic / import composite $P1_{ud}^{c}.X1_{ud}^{c} = \sum_{s} X_{ud}^{cs}.P_{ud}^{cs}$
Equation 8.3: Quantity demand for all users of commodity *c* from source *s* from sub-national origin *r* to destination *d* $XT_{rd}^{cs} = f(XT1_{d}^{cs}, CES[PD_{rd}^{cs} / PU_{d}^{cs}]$
Equation 8.4: Average user price of sub-national source composite $PU_{d}^{cs}.XT1_{d}^{cs} = \sum_{r} XT_{rd}^{cs}.PD_{rd}^{cs}$

[20] The TERM model used in this research consists of 191 equations and 175 sets of variables.

Table 8.2: Variable descriptions

s/no	Variable name	Description
1.	P_{ud}^{cs}	Purchaser prices of commodities.
2.	$P1_{ud}^{c}$	Average price of domestic-import composite.
3.	PD_{rd}^{cs}	Delivered prices of goods.
4.	PU_{sd}^{cs}	User or delivered prices of source-composite goods.
5.	X_{ud}^{cs}	Quantity demand of commodity *c* from source *s* by user *u* in region *d*.
6.	$X1_{ud}^{c}$	Quantity demand for domestic–import composite of commodity *c* by user *u* in region *d*.
7.	XT_{rd}^{cs}	Quantity demand of goods *c,s* from *r* to *d*.
8.	$XT1_{d}^{cs}$	Quantity demand of sub-national source composite goods *c* in region *d*.

Table 8.3: Sets and set elements

Regions (r =1-5)	Taxes (t =1, 2)	Factors (v =1-3)
1. Inner Melbourne	1. Production tax	1. Labour
2. Middle Melbourne	2. Commodity tax	2. Capital
3. Outer Melbourne	**Users (u =1-5)**	3. Land
4. Rest of Victoria (RoV)	1. Producers	
5. Rest of Australia (RoA)	2. Investment	**Sources (s =1,2)**
	3. Households	1. Domestic
	4. Foreign demands	2. Imported
	5. Regional government	

Equation 8.1 specifies demands by regional users for commodities distinguished by just two main sources: domestic and (foreign) imports. Equation 8.2 defines the average price of a domestic-import composite. Users include the regional industries, regional investors, regional households, foreign demanders (i.e. exports) and government. Equation 8.1 is defined under the assumption that each user chooses the domestic-import sourcing pattern of a commodity so as to minimise their costs subject to a Constant Elasticity of Substitution[21] (CES) aggregation across the two sources. In the absence of a relative price change, a user's demand for a commodity from a particular source is proportional to their demand for the domestic-import composite. Where relative prices change, the degree a user will substitute between sources is governed by the sign of the price movement and the CES elasticity.

[21] CES stands for Constant Elasticity of Substitution - as the name suggests, CES function exhibits constant elasticity of substitution between capital and labour (Johansen, 1972, page 178). Imperfect substitution between imports and domestic supplies is a common assumption among CGE models and is known as the "Armington" assumption (Dixon et al., 1982, page 69).

Equation 8.3 and 8.4 treat the substitution possibilities between the sub-national sources of the domestic composite and between the regional ports-of-entry of imported commodities. It will be noticed that demands by regional source contains no user subscript since TERM assumes that all users of a particular commodity in a particular region source their purchases between regions according to proportions that are constant across all users in the region. Equation 8.3 shows that the aggregate regional users will purchase commodities form sub-national sources in accordance with their demands for an all-region composite and movements in relative prices, with substitution towards cheaper regional sources being governed by a CES substitution elasticity. Equation 8.4 defines the margin-inclusive, tax-exclusive delivered price of each regionally-aggregated composite.

8.2.2.2 Industry Demands and Supply

In TERM, producers are price-takers who choose their inputs to minimise cost of producing any particular level of output subject to a CES production function. As might be observed in the previous section, production functions are nested ones. At the top level, individual composite commodities and a composite primary-factor input are combined in fix proportion. At the next level, composite commodities are CES aggregations of domestic and imported sources which in turn are CES aggregations of sub-national sources (as described in the previous sub-section). Again, an industry's primary-factor composite is a CES combination of effective units of labour, capital and land. Within the labour demands, industry users are subject to CES substitutability across occupational mix. At the top level, as stated above, substitution is not possible and inputs are thus chosen in fixed proportions. At the subsequent levels, producers choose their inputs to minimise costs subject to the production function at that level of the nest. As was seen in the previous section, producers' purchases of a particular input depend on their demand for a composite input (i.e. that input and the other inputs with which it is substitutable) and the relative prices of each substitutable input.

The supply of domestically-produced commodities is determined based on the assumption that producers earn zero pure profits and adjust their output to where the price they receive equals marginal cost.

TERM also allows the modelling of industries which have multi-product capabilities. For such industries, their supply of each commodity is subjected to a CET[22] relationship between the industry output prices and the average price of that commodity.

8.2.2.3 Household Demands

As is typical with ORANI-style CGE models, the behaviour of households are modelled in TERM as constrained optimisers where a representative regional household purchases goods in order to obtain the optimal bundle in accordance with its preferences and its amount of disposable income.

In TERM, household demands follow a linear expenditure system[23] in each region (Dixon et al., 1982 page 101). Regional households maximise a Klein-Rubin[24] utility function by choosing among effective units of different commodities based on a cost-minimising CES combination of commodities from the various regions and sources, subject to an aggregate expenditure constraint. Under the CES substitutability specification, households will substitute between goods and between geographical sources of those goods depending on their price (Dixon et al., 1982 page 102).

8.2.2.4 Investment Demands

Similar to other ORANI-style models, TERM treats investors as allocating their funds between industries in order to maximise their rate of return (Horridge et al., 2005). In assembling units of capital in each industry, it is generally assumed in ORANI that each individual industry has a particular commodity-input pattern to capital creation and that industries choose inputs from different sources in order to minimise the cost of creating a unit of capital (Horridge et al., 2005).

---

[22] CET stands for Constant Elasticity of Transformation. According to Horridge (2003, page 25), the CET function is identical to the CES function except that the transformation parameter in the CET has the opposite sign to the substitution parameter in the CES function; that means an increase in the relative price of a commodity would induce a transformation in favour of that output.

[23] A linear expenditure system is one where the expenditure on any commodity is a fixed proportion of total expenditure (Stone, 1954).

[24] Klein-Rubin utility function is a non-homothetic utility whereby a rising income causes budget shares spent on different goods and services to change even though the price ratios are fixed (Horridge, 2003, page 28).

In TERM, capital creation is subjected to a two-tier production function in which effective units of commodities are first formed as a CES combination of source-specific commodities; these are then being put together to a Leontief production function[25].

Investment demands are used to compute an industry investment index in TERM. The index is in turn used to define the gross rate of return and the investment-to-capital ratio. The gross rate of return and the investment-to-capital ratio govern the amount of capital and investment stock in each region in the short and long-run[26].

8.2.2.5 Government Demands

Demands of government are usually dealt with simply in CGE modelling. In the case of TERM, government demands are assumed to be independent of prices and proportional to three corresponding shifters[27] which adjust government demands by regions, commodities and sources. These shifters allow the model user to institute one of a number of ad-hoc rules (e.g. real government current consumption moves with current private consumption, balance budget or fixed real aggregate government expenditure). There are, however, examples in CGE modelling that treat government as constrained optimisers although such cases are rare – some exceptions include Groenewold et al. (2003) and Dixon et al. (2002b).

[25] A Leontief production function is a special case of CES; it is a specification where the factors of production will be used in fixed proportions and there is no substitutability between factors (Dixon et al.1992, page 142).

[26] See Section 8.5.2 for details on the assumption differences between a short-run and long-run simulation in TERM.

[27] A shifter is a variable that can be used to model a movement in the flow level of specific goods and services for specified economic agents (Dixon et al., 1982, page 22). For instance, if there is an upward movement in the demand of the government in region d, this can be modelled by increasing $FGOVTOT_d$ – which is a shifter that moves government demands based on regions. The choice of which shift variables are exogenous also determines at run time which sets of equations are operative in the rest of the model (Horridge, 2003, page 33) – see Section 8.3.2.5 for more information.

8.2.2.6 Export Demands

Similar to government demands, foreign demands are also handled simply in CGE modelling. In TERM, export demands are simulated using a two-stage process. First, regional source-specific exports form a CES composite. National exports are then linked to international demands which are represented by a downward sloping export demand curve for each commodity. The demand curve captures the level of existing demand and the responsiveness of foreigners to changes in Australian supply prices i.e. the export volumes are inversely related to foreign currency export prices via a constant elasticity export demand function.

8.2.2.7 Margins

In order for goods to reach a customer located in a particular region, certain margins services (e.g. transport, wholesale and retail trade) must also be purchased. In the absence of technical change, the use of a particular margin moves proportionally to the commodity whose sale it is facilitating. The regional sourcing of margin services are subjected to a CES substitutability specification. The regional sourcing of a particular margin service (e.g. road transport) facilitating the movement of a commodity over any origin-destination pair is subject to CES substitution possibilities. This is one of the unique features of TERM and part of its sourcing mechanism.

According to Horridge et al. (2005), the flow of commodities and primary factors are valued according to the following 3 methods:

- Basic values = output prices (for domestically-produced goods), or CIF[28] prices (for imported goods)
- Delivered values = Basic + Margins
- Purchasers' values = Basic + Margins + Tax = Delivered + Tax

[28] According to OECD's (2002) glossary of statistical terms, CIF price (i.e. cost, insurance and freight price) is the price of good delivered at the frontier of the importing country. The CIF price would include any insurance and freight charges incurred to that point, or the price of a service delivered to a resident, before the payment of any import duties or other taxes on imports or trade and transport margins within the country.

8.2.2.8 Market Clearing Conditions

In TERM, the usual market clearing conditions (i.e. the total sales and inventories of each industry is set equal to its total production) are specified for industry outputs. However, the following additional market clearing conditions are defined in TERM because of the common sourcing assumption.

- The sales of non-margins commodities across destinations is set equal to the total regional supplies.
- The sales of margins commodities across destinations is set equal to the total regional supplies.
- The sales of margins commodities summed across users is set equal to the supplies of margins commodities summed over regional origins.

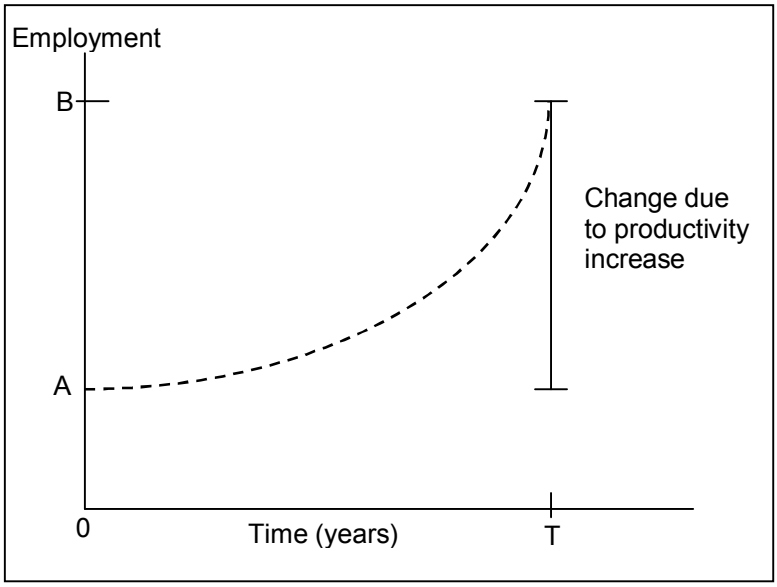
8.2.2.9 Gross Regional Product

TERMS calculates region's Gross Regional Product (GRP) from the expenditure and income approach. Both sides of GRP are set equal by the above-mentioned market clearing conditions.

8.2.3 Simulation Process and Outcome of TERM

The version of TERM used in this research is designed for comparative-static simulations. This is explained using Figure 8.4.

Figure 8.4 shows the values of some variable, say employment, against time. *A* is the level of employment in the base period (period 0) and *B* is the level which it would attain in T years time if the economic scenario under examination - say a productivity increase – took place, all other things being equal. In a comparative-static simulation, TERM would generate the percentage change in employment 100(B-A)/A, showing how employment *in period T* would be affected by the productivity increase alone.



Source: Developed from Harrison and Pearson (1994)

Figure 8.4: TERM's comparative-static interpretation of results

Similar to the other ORANI-style models, the TERM model is solved using the GEMPACK software. GEMPACK is a suite of general-purpose economic modelling software that utilises the linearization technique pioneered by Johansen in the 1960's (Johansen, 1974). It is especially suitable for solving general and partial equilibrium models (Harrison et al., 1996). Harrison and Pearson (1994a, Section 2) explained that solving the ORANI-style models within GEMPACK is done in the context of a simulation using the following 3 steps.

1. Writing down the equations that describe the economic behaviour of each agent in an algebraic form.
2. Setting up a database matrix which is to be used as the starting point of the simulation.
3. Preparing a text file using the TABLO language, that contains the equations (which describe the economic behaviour) and information about the data specified. This file is called a TABLO Input file since TABLO is the name of the GEMPACK program that processes this file and converts the information on it to a form suitable for running simulations on the model.

According to Harrison and Pearson (2002, page 3-87), TABLO Input files contain the equations of a model written down in a syntax that is very similar to ordinary algebra. They emphasised that once the equations are written down in ordinary algebra, it is very easy to transfer them into the TABLO Input file.

When the program TABLO processes the TABLO Input file, it automatically linearises the equations and converts the whole TABLO Input file into a linearised TABLO Input file (which is called the associated linearised TABLO Input file). Thereafter, the model will proceed using this associated linearised TABLO Input file as if it were the actual TABLO file (Harrison and Pearson, 1994, Section 2.5.1). Once the simulation is carried out, the software reports changes or percentage changes in selected variables as an output (Harrison and Pearson, 1994, page 17).

A feature of the GEMPACK software is its capability of eliminating linearization errors that would arise from a simple adoption of the Johansen technique. This is accomplished by employing the Johansen technique through an iterative multi-step approach. Dixon et al. (1982, Section 8.3) provide a detailed mathematical explanation that demonstrates that a combination of multi-steps and extrapolation methods will provide the same accurate solution as can be obtained from a non-linear solution.

8.3 Modifications to TERM

Modifications are made to this version of TERM to facilitate this study's application. This section identifies the limitations of TERM and reports the key modelling assumption and alterations made within the possible scope of this research to enable the model to shed light on how a productivity shock might flow through at the regional level.

8.3.1 Model Limitations

Investigation undertaken by this research shows that there are some limitations with the current TERM database which may have implications for this study. These limitations are of the following two main types.

1. The first limitation relates to the current TERM database incorporating the CBD in a wider region, the Inner Melbourne region, which displays a different pattern in the spatial distribution of industries to the CBD.
2. The regional industries have been disaggregated on the basis of employment by place of residence. In general, this does not pose a problem for TERM modelling as the regions are, for the most part, sufficiently large to cover an entire metropolitan area, with most people working and living in a particular region. However, this disaggregation approach is a concern to this study where the Melbourne Metropolitan area is split into three regions, and the focus is the Melbourne CBD, a region in which most workers commute from elsewhere in Melbourne metropolitan area. This means that it is not reasonable to assume that all wage income is earned in the region where households reside.

Tables 8.4 elaborate the first limitation. The table compares the employment distribution of Inner Melbourne region (which the CBD is a subset of) based on data from TERM and the Australian Bureau of Statistics (ABS) as well as that of the Melbourne CBD from the Census of Land Use and Employment (CLUE) (City of Melbourne, 2006). For ease of comparison, the table has been formatted to follow the industrial structure adopted in the TERM database.

Table 8.4: Employment distribution across industries for CBD and Inner Melbourne Region – TERM model database versus ABS data

Region	Inner Melbourne region		CBD
1 Industries	2 TERM model	3 ABS data	4 CLUE data
1 Primary	0.55%	0.38%	0.80%
2 FoodDrinks	0.96%	0.53%	0.11%
3 OthManufact	**7.79%**	**4.33%**	**0.88%**
4 Utilities	0.73%	0.95%	1.24%
5 Construction	3.34%	2.96%	0.93%
6 Trade	**13.90%**	**10.58%**	**7.85%**
7 HotelsCafes	8.17%	6.64%	8.41%
8 RoadTransprt	0.74%	1.04%	0.86%
9 RailTransprt	0.14%	0.20%	0.16%
10 OtherTrans	0.66%	0.93%	0.77%
11 WaterTrans	0.09%	0.13%	0.10%
12 AirTransport	0.87%	1.22%	1.01%
13 Communicatn	**1.97%**	**5.71%**	**9.73%**
14 BankInsure	**7.97%**	**12.57%**	**20.72%**
15 OwnerDwellng	0.00%	1.67%	0.78%
16 BusSrvces	14.53%	13.66%	14.73%
17 TechServic	8.65%	8.13%	8.77%
18 GovAdminDef	**5.10%**	**7.65%**	**11.57%**
19 EducHealth	**17.20%**	**12.83%**	**5.53%**
20 ChldCommCare	1.30%	0.97%	0.42%
21 OthServices	5.32%	6.93%	4.63%
Total	100.00%	100.00%	100.00%

Source: TERM database, ABS (2006f) and City of Melbourne (2006)

Column 2 Table 8.4 shows the distribution for Inner Melbourne region that is extracted from the TERM database. Columns 3 and 4 show the distribution across industries in Inner Melbourne region and the CBD, based on the actual employment and occupation distribution as given in ABS (2006f) and the CLUE (City of Melbourne, 2006) respectively.

From Table 8.4, it can be established that there are some differences between the employment structure of the actual Inner Melbourne region and that modelled in TERM. Comparison of columns 2 and 3 of Table 8.4 suggests that the TERM database over-represents industries such as Manufacturing (row 3 - 7.79% in TERM as compared to actual 4.33%), Trade (row 6 - 13.9% in TERM as compared to actual 10.58%) as well as Education and Health (row 19 - 17.2% in TERM as compared to actual 12.83%) in the Inner-Melbourne Region - these are shown shaded in grey in Table 8.4.

On the other hand, employment in the TERM database is lower than the actual situation for industries such as Information Technology and Communication (row 13 - 1.97% in TERM as compared to actual 5.71%), Banking and Insurance (row 14 - 7.97% in TERM as compared to actual 12.57%) as well as Government Administration services (row 18 - 5.10% in TERM as compared to actual 7.65%) in the Inner-Melbourne Region - these are shown shaded in black Table 8.4.

The above mentioned differences are even more significant in comparison to the actual CBD employment and occupation structure (see column 4). Past studies (such as the work of Graham (2006b)) have suggested that regions with higher concentration of knowledge-based sectors enjoy greater benefits from higher agglomeration. The above limitations of the TERM database for the current application mean that the TERM modelling approach is likely to result in a conservative estimate of the economic value for the productivity impacts on Inner Melbourne region (and hence the CBD) associated with rising rail congestion.

8.3.2 Modelling Assumption and Model Alterations

This section presents the key modelling assumption and model alterations made within the possible scope of this research to address the limitations identified earlier.

8.3.2.1 Key Modelling Assumption

To create a sixth region in TERM to represent Melbourne CBD alone would involve complex data manipulation and extensive re-configuration of the TERM structure which is beyond the scope of this research. As an urban rail constraint affecting Melbourne CBD is likely to impact the accessibility of Inner Melbourne region in the same manner, this research assumed that any associated dis-agglomeration effects affecting Melbourne CBD can be treated as the estimated regional impact on Inner Melbourne region so as to facilitate the TERM modelling.

Based on this assumption, any shocks estimated for the CBD are therefore imposed directly on the Inner Melbourne region in TERM. On the same note, any impact on the Inner Melbourne region is also assumed to impact Melbourne CBD's economy to the same extent. Put in another way, TERM's output for Inner Melbourne region are assumed to proxy the impact on Melbourne CBD – for example, if Inner Melbourne region's GRP is anticipated to fall by 1% under a productivity deterioration scenario, it is assumed that the CBD's economy will also be affected by 1% and vice versa.

While this is envisaged to yield a conservative estimate of the impact to Melbourne CBD (since the CBD has a slightly higher concentration of knowledge-based firms compared to Inner Melbourne region), it is the most reasonable manner to carry out the simulations given the current limitations of TERM.

An examination of MITM's outputs suggests that the change in the generalised cost of trips entering Inner Melbourne region and the CBD under an urban rail capacity constraint scenario in the AM peak are in the same order of magnitude. In addition, the weighted average agglomeration elasticity[29] value for Inner Melbourne region is also close to that for the CBD[30]. As the generalised cost of trips and agglomeration elasticities are both used as inputs to estimate the associated productivity shocks, the above assumption that Inner Melbourne region would behave in the same way as its subset (the CBD) under a productivity deterioration scenario, is considered reasonable.

8.3.2.2 Model Alternations

To address the second and more crucial issue identified in Section 8.3.1, this research modified the TERM theory so that labour, capital and land rental shares of household income for a region is earned from a weighted sum of regional locations of employment, with the weights being based on commuter travel patterns. It is assumed that households undertake their consumption expenditure in the region in which they reside. Details of how the household income from each primary factor was estimated and how this modification was applied in TERM are reported next.

[29] As explained in Section 2.6.4 (page 51), agglomeration elasticity refers to the elasticity between urban productivity and the accessibility between workers and firms.

[30] See Section 8.5 for more details on the changes in the generalised costs of trips into Inner Melbourne region and the CBD as well as their respective weighed average agglomeration elasticities.

1. Labour Income of Each Region

Table 8.6 presents the proportion of each region's total labour income earned from the various regions of employment. This table was derived by first distributing the regional sums of employment (based on ABS (2006e), (2006f), (2006h), (2006i) and (2006j)) to the respective regions of residence (based on journey-to-work data from VicRoads (2008a)). This employment distribution is then applied on the total wage bill of each region of employment (extracted from TERM) to estimate the total labour income earned by the workers residing in each region.

Table 8.5 suggests that residents of Inner Melbourne region earned 36% of their labour income from the Inner Melbourne region, 41% from the Middle Melbourne region, 10% from the Outer Melbourne region and the remainder from RoV and RoA.

Table 8.5: Proportion of each region's total labour income from the various regions of employment ($LAR_{r,d}$)

Region of Employment (d)	Region of residence (r)				
	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Inner Mel region	36%	12%	5%	0%	0%
Middle Mel region	41%	65%	30%	12%	0%
Outer Mel region	10%	16%	60%	13%	0%
RoV	5%	4%	4%	69%	1%
RoA	7%	2%	2%	6%	99%
Total	100%	100%	100%	100%	100%

Source: Developed from ABS (2006e), (2006f), (2006h), (2006i), (2006j), VicRoads (2008a) and total wage bill from the TERM model.

2. Capital Rental Income of Each Region

Secondary research conducted by this study suggests that there is no published consolidated information regarding the ownership of capital stocks for any geographical levels in Australia. To facilitate the estimation of capital rental income for each region of residence, the ownership of capital stocks of the various sectors as shown in Table 8.6 was assumed – for example, 75% of the capital stocks for those industries in the first group were assumed to be owned by the residents of the region in which the capital was employed; the remaining 25% are assumed to be owned by residents of the other regions; the latter was distributed to the various regions based on the population of each region.

These assumptions were based on assessment of data from various sources such as the employment size of firms for various sectors in the CBD (City of Melbourne, 2008) and other regions (e.g. ABS, Service Skills Victoria, 2007 and SGS Economics and Planning Pty Ltd, 2008) and assuming that small businesses[31] are largely owned by residents in each region.

Table 8.6: Ownership of capital stocks among regions

Industries		% own by region of consumption	% own by other regions
1 Primary	5 Construction	75%	25%
2 FoodDrinks	6 Trade		
3 OthManufact	15 OwnerDwellng		
	20 ChldCommCare		
7 HotelsCafes	17 TechServic	50%	50%
8 RoadTransprt	19 EducHealth		
16 BusSrvces	21 OthServices		
4 Utilities	11 WaterTrans	25%	75%
9 RailTransprt	12 AirTransport		
10 OtherTrans	13 Communicatn		
	14 BankInsure		
18 GovAdminDef		50%	50%

Note: The industrial structure was based on that adopted in TERM as the amount of capital rental consumed (by each industry) in each region extracted from TERM was needed for the calculation.

Based on these assumptions, the capital rental expenditure for the various sectors in each region (extracted from TERM) was distributed to the region itself and the other regions as rental income. Table 8.7 presents the proportion of each region's total capital rental income earned from the various regions of consumption - for example, residents of Inner Melbourne region earned 27% of their capital rental income from the capital stock consumed in Inner Melbourne region, 2% from the Middle Melbourne region, 2% from the Outer Melbourne region and so on.

Table 8.7: Proportion of each region's total capital rental income from the various regions of capital consumption ($CAR_{r,d}$)

Region of Consumption (d)	Region of residence (r)				
	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Inner Mel region	27%	0%	1%	0%	1%
Middle Mel region	2%	28%	3%	2%	5%
Outer Mel region	2%	2%	0%	2%	4%
RoV	1%	1%	2%	30%	3%
RoA	68%	68%	94%	66%	86%
Total	100%	100%	100%	100%	100%

[31] ABS (2001a) defines small business as one that has less than 20 employees.

3. Land Rental Income of Each Region

Table 8.8 presents the proportion of each region's total land rental income from the various regions of consumption. The table was derived using the total rental from land stock consumed in each region (extracted from TERM) and based on the following assumptions:

- 25% of the land stock in Inner, Middle and Outer Melbourne region is owned by the residents of that region; the other 75% ownership belongs to residents of other regions – it is assumed that land across the regions are totally owned by Australians so as to be consistent with TERM which models only the economy of Australia ;
- 75% of the land stock in RoV are owned by the residents; the remaining 25% belongs to residents of other regions;
- 50% of the land stock in RoA are owned by the residents; the remaining 50% belongs to residents of other regions; and
- The shares owned by the other regions are distributed amongst the regions according to their residential population.

Table 8.8: Proportion of each region's total land rental income from the various regions in which land is located ($LDRS_{r,d}$)

	Region of residence (r)				
Region of land location (d)	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Inner Mel region	0%	0%	0%	0%	0%
Middle Mel region	0%	0%	0%	0%	0%
Outer Mel region	1%	1%	2%	0%	1%
RoV	4%	4%	4%	64%	11%
RoA	95%	95%	94%	36%	87%
Total	100%	100%	100%	100%	100%

4. Income Shares of Each Primary Factor

The incomes of each region earned from labour and the rental of capital and land stocks were then put together to work out the shares of income from each primary factor. These are presented in Table 8.9. For example, about 70% and 28% of the total income of Inner Melbourne region are generated by capital rental and labour respectively; land rental contributes the remaining 2%.

Table 8.9: Income shares of each primary factor

Primary Factor	Region of residence (*r*)				
	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Labour share of income (S_r^L)	28%	38%	43%	40%	62%
Capital rental share of income (S_r^K)	70%	60%	56%	56%	37%
Land rental share of income (S_r^{Land})	2%	2%	2%	3%	1%

The percentages shown in Tables 8.5, 8.7, 8.8 and 8.9 are set up in Equation 8.5 which was built into TERM to estimate the household income for each region (*winc*$_r$).

$$winc_r = [S_r^L \sum_d LAR_{r,d} * wlab_io_d] + [S_r^K \sum_d CARS_{r,d} * wcap_i_d] + [S_r^{Land} \sum_d LDRS_{r,d} * w\ln d_i_d] \quad \text{(Equation 8.5)}$$

where

- S_r^L, S_r^K, S_r^{Land} are the respective primary factor shares of income of each region of residence, *r* (Table 8.11)
- $LAR_{r,d}$ is the <u>share</u> of labour income earned by region of residence, *r* from region of employment, *d* (Table 8.7)
- $CAR_{r,d}$ is the <u>share</u> of capital rental income earned by region of residence, *r* from region of consumption, *d* (Table 8.9)
- $LDRS_{r,d}$ is the <u>share</u> of land rental income earned by region of residence, *r* from region of consumption, *d* (Table 8.10)
- $wlab_io_d$ is the <u>percentage change</u> in total labour wage bill of region of employment, *d*
- $wcap_i_d$ is the <u>percentage change</u> in total capital rental consumed by region of employment, *d*
- $w\ln d_i_d$ is the <u>percentage change</u> in total land rental consumed by region of employment, *d*.

8.3.2.3 Additional Equations for Long-Run Simulations

For long-run (LR) simulations, TERM assumes that capital stocks (and hence investments) are free to adjust in such a way that maintains the rates of return. Such movements of capital and investment would, however, make it more difficult to interpret the results of LR simulations at the regional level since labour is also mobile. To assist in the explanation of the LR results, 2 additional equations are introduced to TERM to tie down the aggregate level of investment and capital nationally. Under this simplified assumption, the LR productivity shock result is entirely explainable by the reduction in the GRP of Inner Melbourne region.

The rationale for tying down capital stock at the national level is to fix the global effects on the capital stocks on every region and every industry so that any movement in the capital stock across sectors and regions can be fully attributed to the productivity shock. As the productivity deterioration in Inner Melbourne region is not likely to affect business confidence and hence the national capital / investment ratio in Australia, investment is allowed to move across regions in tandem with the aggregate capital stocks.

These 2 new equations are represented as Equations 8.8 and 8.9 in Table 8.10. They are activated in the LR simulations using closure[32] swaps. This is achieved by swapping $FGRET_{id}$ for *FINV1* and $FGGRO_{id}$ for K_{id} for LR simulations. The closure swaps will exogenise the $FGGRO_{id}$ and $FGRET_{id}$ variables and turn on Equations 8.8 and 8.9. On the other hand, making K_{id} and *FINV1* endogenous, would turn off Equations 8.6 and 8.7 which are used to calculate the capital and investment level in the short-run (SR).

[32] In GEMPACK terminology, a closure is a list of exogenous variables (Horridge, 2003, page 56). This is to clearly define which variables are exogenous and which are endogenous so as to close the model. The number of endogenous variables must be equal to the number of equations in order to close the model.

Table 8.10: Equations that define investment and capital in each region in TERM

Equations
Equation 8.6: Investment-to-capital ratio $GGRO_{id} = X2TOT_{id} / K_{id}$
Equation 8.7: ORANI investment rule $GGRO_{id} = FINV1 * [(GRET_{id})^2 / Invslack]^{0.33}$
Equation 8.8: Capital level for each region in LR $GGRO_{id} = FGGRO_{id} + GGRO_S$
Equation 8.9: Investment level for each region in LR $GRET_{id} = FGRET_{id} + GRET_S$

Table 8.11: Variable descriptions

s/no	Variable name	Description
1.	$FGRET_{id}$	Shifters to activate Equation 8.9 in LR.
2.	$FGGRO_{id}$	Shifters to activate Equation 8.10 in LR.
3.	*FINV1*	Investment shift variable.
4.	$GRET_{id}$	Gross rate of return – ratio of capital to price of new capital.
5.	$GGRO_{id}$	Investment-to-capital ratio.
6.	$GRET_S$	National average gross rate of return.
7.	$GGRO_S$	National average investment-to-capital ratio.
8.	$Invslack$	Investment slack variable for exogenizing national investment.
9.	K_{id}	Demand for capital.
10.	$X2TOT_{id}$	Investment by industry.

8.4 The TERM Modelling Approach

TERM contains no modelling of agglomeration economies since it is based on a constant returns to scale assumption (Gwee and Madden, 2010). To the best knowledge of the author, while there are a few studies that modelled agglomeration economies in transport (Section 2.6.5), there is no published work to date that uses a CGE modelling approach to examine agglomeration economies in urban rail. Therefore, this research carried out preliminary investigation to explore how agglomeration effects in urban rail could be reasonably simulated in TERM. This section reports the experimental modelling work conducted.

8.4.1 Wage – Employment Shock Approach

The initial idea was to model agglomeration effects associated with an urban rail constraint using the remuneration and employment impacts gathered from the CBD employer survey to shock TERM. The underlying assumption in this approach is that the CBD employers' estimates for both the impact on the real wage and on employment can be treated as the estimated regional impacts for Inner Melbourne region.

The survey suggests a link between an increase in real wage and a fall in employment with the agglomeration effects associated with an urban rail constraint. However, as there is no way to ascertain whether the survey participants have indeed factored in agglomeration effects in their estimation, it is difficult to isolate the agglomeration effects purely based on the survey results – Figure 8.5 explains this issue further.

Figure 8.5(a) shows the notional labour demand and supply curves for the Inner Melbourne region in an equilibrium state. The Y-axis represents the real wage while the X-axis represents the quantity of labour aggregated across the region. Equilibrium in the labour market is established at position A where the downward sloping demand curve intersects the upward sloping supply curve.

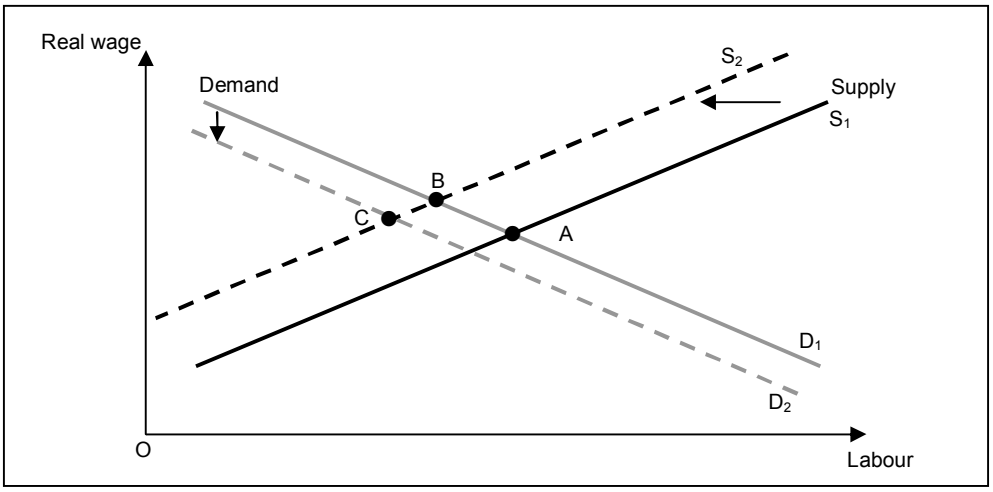


Figure 8.5: Labour supply and demand curves for Inner Melbourne region

The employers have indicated that they are prepared to increase their remuneration to compensate their workers for the increasing difficulty to get to work due to the raising rail congestion. With reference to Figure 8.5, the increasing congestion moves the labour supply curve from position S_1 to S_2 because, at any real wage rate, the employees are less prepared to work than they were before. This will move the equilibrium state for the region to position B.

The theory of agglomeration suggests that the poorer accessibility of the region might cause its productivity to deteriorate. It this happens, there will be a movement of the labour demand curve from D_1 to D_2. The equilibrium state then becomes position C. As illustrated in Figure 8.5, it is not possible to ascertain from the survey results whether the equilibrium position will move from A to B or from A to C.

To explore how the survey findings could be used to simulate agglomeration effects in TERM, preliminary simulations were first carried out in TERM to assess how a rise in real wage and a technological deterioration would impact employment in Inner Melbourne region. As part of the experiment, a Back-Of-The-Envelope (BOTE) model was used to assess whether the TERM model is behaving reasonably within standard labour market theory and data.

8.4.1.1 Back-Of-The-Envelope (BOTE) Model

A stylized model of the economy of Inner Melbourne region is that it produces a single product, *Y* according to the production function represented by Equation 8.10. *F* indicates that the function is constant returns to scale (i.e. doubling inputs of capital and labour doubles output)

$$Y = \frac{1}{A} F(K, L) \qquad \text{(Equation 8.10)}$$

where

- *Y* is the regional output
- *A* is a technological coefficient
- *K* is the capital
- *L* is the labour.

The economy of Inner Melbourne region chooses inputs *K* and *L* to maximise profit as follows:

$$\text{Profit} = PY - WL - QK \qquad \text{(Equation 8.11)}$$

where

- *P* is the price of output
- *W* is the wage rate
- *Q* is the rental on capital.

The standard first-order condition for profit maximisation shows that representative firms in a region such as Inner Melbourne region choose their employment in the SR so as to equate its marginal output with the real wage i.e.

$$\frac{\partial \Pr ofit}{\partial L} = P(\frac{\partial Y}{\partial L}) - W = 0$$

$$\therefore \frac{\partial Y}{\partial L} = \frac{W}{P}.$$

Following the profit maximisation condition, Equation 8.10 can be represented in the following functional form:

$$(\frac{W}{P}) = \frac{1}{A} F_L(\frac{K}{L}) \qquad \text{(Equation 8.12)}$$

The real wage of labour can be represented by w/p_c where P_c is the price of consumption. Multiplying both sides of Equation 8.12 with P/P_c allows the real wage to be introduced into the equation as follows:

$$(\frac{W}{P}) * (\frac{P}{P_c}) = \frac{W}{P_c} = (\frac{P}{P_c}) * \frac{1}{A} * F_L(\frac{K}{L}) \qquad \text{(Equation 8.13)}$$

What does Equation 8.13 say about the SR effect of a real wage increase in Inner Melbourne region? A rise in real wage in the Inner Melbourne region would mean that the left-hand side of equation 8.13 goes up. Assume for the moment that there is no change in the price of goods produced relative to the price of goods consumed (i.e. P/P_c) in Inner Melbourne region. With the technological variable (*A*) fixed, $F_L(K/L)$ must increase in order for Equation 8.13 to be in equilibrium. In the SR, there is no change in capital stock, *K*. Given that F_L is an increasing function of K/L (which means that under a constant returns to scale, the marginal productivity of labour depends on the K/L ratio), the demand for labour, *L* therefore has to fall. This is depicted as the shift of the labour supply curve from position S_1 to S_2 in Figure 8.5.

On the other hand, what does Equation 8.13 say about the short term effect of a deterioration in productivity (due to agglomeration effects) in Inner Melbourne region? With w/p_c, fixed in the SR and P/P_c barely moving in the Inner Melbourne region, Equation 8.13 suggests that an increase in *A* (which represents a productivity deterioration) would also cause $F_L(K/L)$ to rise and with *K* held constant in the SR, this would lead to a fall in the demand for labour, *L* in the Inner Melbourne region. This is shown as the movement of the labour demand curve from D_1 to D_2.

8.4.1.2 Experiment

Preliminary simulations were first carried out in TERM to assess how a rise in the real wage and a productivity deterioration might impact employment in Inner Melbourne region. For the first simulation, the *flab_io ("InrMlbrnVic"),* which is the wage shifter variable for the Inner Melbourne region, was exogenised. For the second simulation, the exogenous variable, *aprim ("InrMlbrnVic")* which governs the technical change in the productivity of all primary factors within the Inner Melbourne region, was shocked.

A SR wage shock of +2.09% to *flab_io ("InrMlbrnVic")* yielded an employment impact of about -0.95% which is close to the survey findings (-0.97%). On the other hand, a +1.00%[33] shock to *aprim ("InrMlbrnVic")* yielded an employment impact of about -0.23%. A BOTE analysis estimated a weighted (according to wage share) labour demand drop of -0.94% which is close to the -0.95% estimated by TERM for the wage shock simulation. The BOTE analysis also estimated a weighted (according to wage share) drop of -0.22% in labour demand for the second simulation. Both BOTE analyses suggest that the TERM model is behaving reasonably within standard labour market theory and data. Details of the BOTE are presented in Appendix F of this thesis.

After establishing that TERM is behaving reasonably, the initial idea was to impose both the increase in the real wage and the fall in the employment simultaneously on TERM so as to simulate agglomeration effects associated with an urban rail constraint. Under such conditions, Equation 8.13 suggests that the technological variable, *A* for the Inner Melbourne region will move to accommodate the difference between the employment result that TERM computes for the real wage and the employment impact predicted by the survey respondents. This movement in *A* will yield an indication of the productivity deterioration accompanying a fall in agglomeration in the Inner Melbourne region associated with an urban rail constraint.

For this SR simulation, the closure selected was to exogenise both the labour and real wage variables for Inner Melbourne region and to endogenise *aprim ("InrMlbrnVic")* variable. A wage shock of +2.09% on *flab_io ("InrMlbrnVic")* and an employment shock of -0.97% on x*lab_io ("InrMlbrnVic")* are imposed simultaneously on TERM.

[33] As mentioned previously, a positive shock to the aprim variable represents a productivity deterioration in the primary factors.

The experimental model runs predicted an increase in the *aprim ("InrMlbrnVic")* variable (i.e. a drop in the productivity of primary factors) when both the increase in the real wage and the fall in the employment are applied simultaneously on TERM. While this result suggests that the model is moving in the right direction, there are several reasons against employing this method to solve for agglomeration effects in TERM.

1. The wage-employment shock approach implicitly assumes that the CBD employer survey participants have taken agglomeration effects into consideration in their employment plan prediction. There is, however, no way of determining whether this was indeed the case.
2. The divergence in the TERM and survey estimates of labour demand fall could be due to many factors pertaining to the differences between the TERM model and the perceptions / beliefs of the employers who participated in the survey. For example, even if the employers had used the same theory as that underlying TERM, they might have a different idea on key parameters to which the results are sensitive (such as the ease of capital-labour substitution). In truth, however, the survey participants are unlikely to have used any specified formal theory. In such circumstances, relying on small differences between TERM result and the participant's prediction is difficult to justify.
3. There are no ostensibly compatible wage and employment estimates to shock the model for the LR simulations[34]; but even if such results were available, they would be more difficult to interpret at the regional level as both labour and capital are mobile in the long term and competitive effects tend to dominate regionally.
4. The existence of PETE, which is a credible method, offers an alternative modelling approach as presented in the next section.

While the above experiment concluded that it is not appropriate to use the wage-employment shock approach to solve for agglomeration effects in TERM, it does indicate that the TERM model is capable to carry out greater modelling of regional labour movement. This is a potential area for future research which may be useful for examining the labour market effects associated with transport improvement.

[34] The long term wage and employment information were not collected through the survey as feedback from the participants during the pilot test suggest that it would not be reasonable to expect the employers to predict so far into the future.

8.4.2 Productivity Shock Approach

According to the theory of agglomeration (Chapter Two), the reduction in the Inner Melbourne region's employment concentration (i.e. the number of employees per unit area) due to rising rail congestion is envisaged to have some detrimental impact on the region's productivity. Adopting this argument, this research developed a modelling approach which involves the following two steps.

1. Undertake an outside calculation using MITM's output (i.e. change in generalised cost of trips) to estimate the impact that an urban rail constraint has on agglomeration economies.
2. Impose this impact on TERM by way of a productivity shock.

The output from TERM using such an approach can then be interpreted as the productivity loss due to dis-agglomeration effects associated with an urban rail constraint.

In step (a), the productivity shocks were estimated based on the PETE method using agglomeration elasticities from the UK Department for Transport (DfT) (2009) and the New Zealand Transport Agency (NZTA) (2008) as there are no agglomeration elasticity estimates for the Melbourne metropolitan area (PricewaterhouseCoopers, 2008). Details of how the productivity shocks were estimated are presented in the Section 8.5.

As highlighted in Section 2.6.4, the agglomeration elasticities adopted by DfT (2009) and NZTA (2008) were based on the work of Graham (2005, 2006a, 2006b, 2007b). He estimated the agglomeration elasticities for various sectors in the UK using a Translog Production Function model that made use of the turnover of the firms in the study region as the dependent variable, with primary factors (namely labour and capital) and an effective density measure of employment agglomeration as independent variables. The agglomeration elasticities for the sectors are essentially the resultant coefficients for the effective density variable generated by his Translog model.

Since the productivity shocks were estimated from agglomeration elasticities, they should only be applied on the primary factors in the Inner Melbourne Region in TERM. This is to maintain consistency with the specifications that Graham (2005, 2006a, 2006b, 2007b) used in his Translog model from which the agglomeration elasticities were derived. Therefore, under step (b) of this approach, the closure chosen for the productivity shock is to shock the *aprim ("InrMlbrnVic")* variable which augments the productivity of all primary factors within the Inner Melbourne region. Put in another way, step (b) essentially changes the underlying constant return to scale assumption in TERM to increasing return to scale[35] for the primary input factors in Inner Melbourne region so as to proxy agglomeration effects.

The deterioration in its productivity is expected to impact the GRP of Inner Melbourne region. Assuming that the CBD behaves in the same manner as the Inner Melbourne region, the GRP of the CBD is estimated to also fall by the same percentage as the Inner Melbourne region. This drop in the CBD's GRP would give an indication of the economic value of the dis-agglomeration effects associated with an urban rail constraint and can be compared against the agglomeration dis-benefits estimated using PETE and the employment suppression impact measures.

As explained in the BOTE model (Section 8.4.1.1), a productivity deterioration in a region would lead to a fall in its employment demand. The possible labour market movement due to the productivity deterioration is explained using Figure 8.6. Figure 8.6(a) shows the labour-demand curves for a 2-region economy in an equilibrium state. The Y-axis represents the real wage while the X-axis represents the quantity of labour aggregated across both regions. The Region 1 curve has its origin, O_1 on the left-hand side while the Region 2 curve has its origin, O_2 on the right-hand side. In line with the diminishing marginal productivity, the Region 1 curve is downward sloping towards the right and, since Region 2's labour demand is measured from right to left, the Region 2 curve is downward sloping towards the left. The X-axis is of a fixed length in order to reflect the long term assumption of fixed national employment. The present equilibrium state is established with the market-clearing wage, W, the length O_1L and O_2L along the X-axis representing the current labour demand in Region 1 and Region 2 respectively.

[35] According to McTaggart et al. (2007), with given inputs, increasing returns to scale occur if the percentage increase in output is higher than the percentage increase in inputs (i.e. if a firm doubles its inputs, its output will more than double).

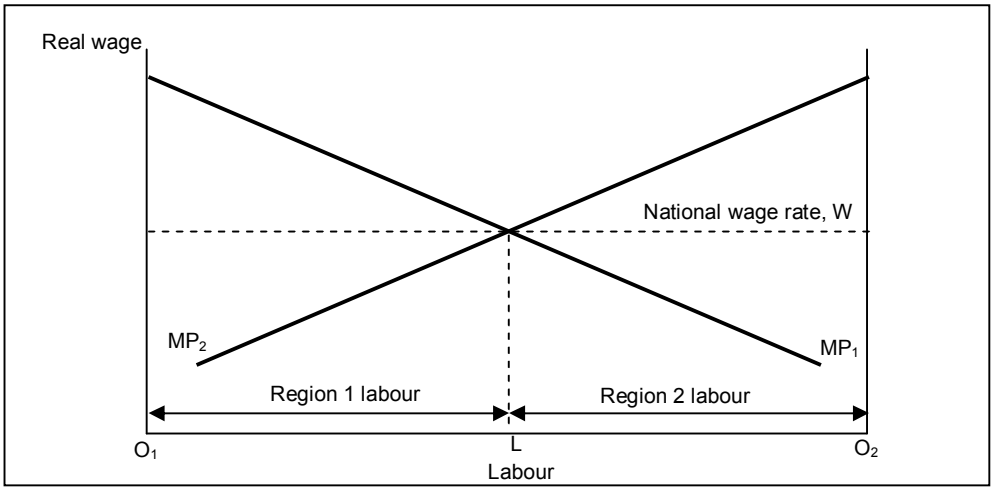


Figure 8.6(a): Present equilibrium status

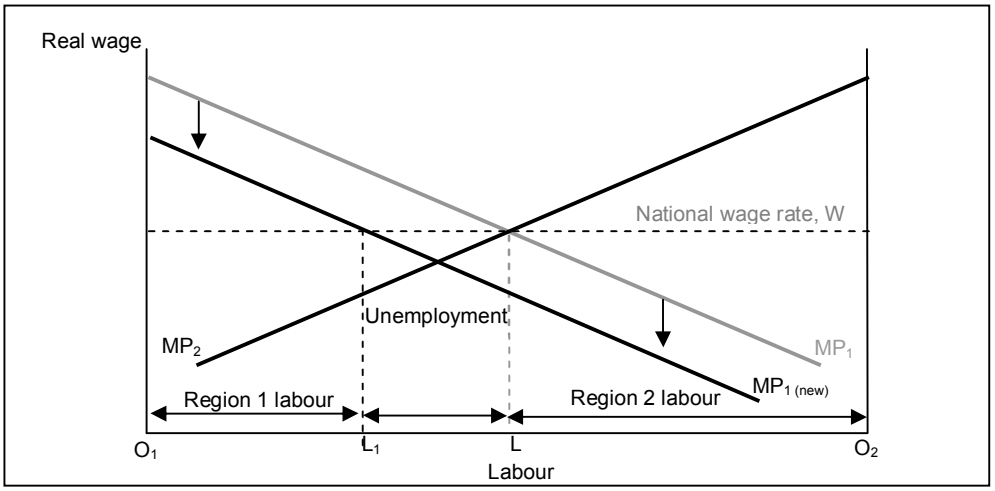


Figure 8.6(b): Short run effects of productivity deterioration in Region 1

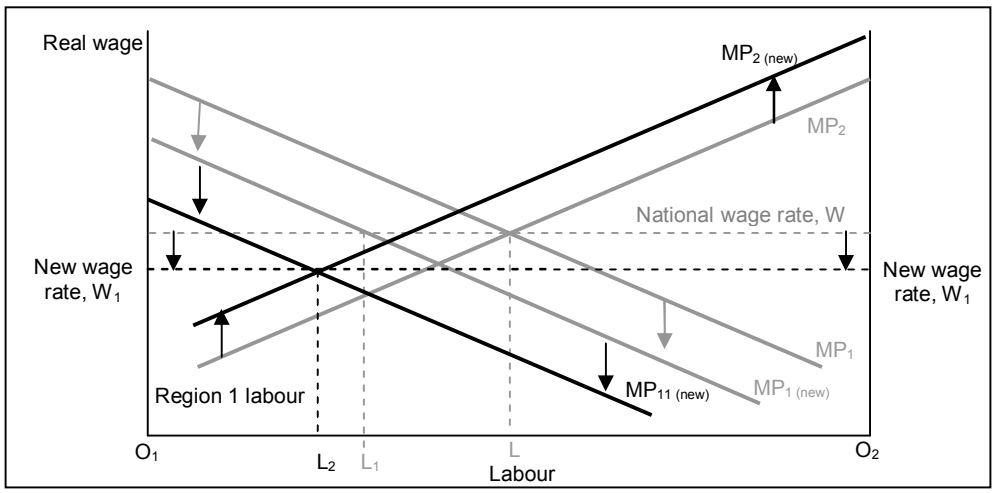


Figure 8.6(c): Long run effects of productivity deterioration in Region 1

Figure 8.6: Productivity deterioration effect on labour market movement in short and long term in a 2-region economy

Figure 8.6(b) illustrates the short term labour market effect of a productivity deterioration in the Inner Melbourne region. The productivity drop is represented by a downward shift of the Region 1 marginal productivity curve. The new position is depicted as $MP_{1(new)}$. With the real wage rate of Region 1 remaining unchanged in the SR, the productivity deterioration is envisaged to cause a fall in the labour demand for Region 1. The new labour demand of Region 1 is now O_1L_1. In this instance, the length L_1L along the horizontal axis represents the fall in Region 1's labour demand (i.e. unemployment) due to the drop in productivity. This is the direct impact on Region 1.

With labour mobile in the longer term and the presence of unemployment, there is downward pressure on the economy-wide real wage to eliminate the unemployment nationally. This causes the real wage to fall in both regions. The surplus labour in Region 1 would move to Region 2 to seek new job opportunities. In addition, capital and investment stocks are also moving out of Region 1 in the long term due to its lower productivity. This causes a further downward shift in the marginal productivity curve of Region 1 to position $MP_{11(new)}$. The surge of capital into Region 2 also causes an upward shift in the Region 2 marginal productivity curve to $MP_{2(new)}$. A new equilibrium state is achieved when the national wage rate reaches a new equilibrium position, W_1 and the employment of Region 2 hits O_2L_2. Under this new equilibrium position, the labour demand of Region 1 drops further to O_1L_2 which is lower than its demand in the short-term.

It is to be highlighted that the employment impact due to the productivity shock cannot be compared against the employment suppression impact estimated in the preceding chapters. The former is an outcome of the productivity lost which causes a downward shift of the labour demand curve. The fall in employment essentially represents the difference in the employment drop estimated by the survey and TERM via the wage-employment shock approach.

The employment suppression impacts derived in the earlier chapters, on the other hand, are estimates of the possible drop in the CBD's labour supply due to the rising congestion. As explained in Figure 8.5, the higher congestion level essentially shifts the labour supply curve towards the left, thus causing labour supply to fall. Productivity elasticities[36] are applied on them in order to estimate their productivity loss associated with agglomeration effects.

[36] As defined in Section 2.6.4, productivity elasticity refers to the elasticities between productivity gains and urban size / employment concentration (i.e. the number of workers per unit area).

It was concluded from the earlier experiment (Section 8.4.1.2) that the TERM model is behaving reasonably under standard labour theory when a productivity shock is imposed. Therefore, the productivity shock approach offers an appropriate way to simulate the impacts of agglomeration associated with urban rail capacity constraints.

8.5 Estimation of Productivity Shocks

This section outlines how the productivity shocks were estimated based on the PETE method. To be consistent with the generalised cost of trips into the CBD presented in Chapter 5, the productivity shocks were also estimated on the basis of Melbourne CBD. As reported in Section 8.3.2.1, any economic impact on Melbourne CBD is assumed to be the estimated regional impact for Inner Melbourne region. The productivity shocks derived in this section are therefore imposed on the Inner Melbourne region in TERM directly.

8.5.1 Methodology

The productivity shocks associated with a 10% rail capacity constraint have been calculated in this research using the PETE method i.e. the approach used by DfT (2009) and NZTA (2008) to estimate agglomeration benefits. An outline of the calculation is presented below. The details of the computation are shown in Appendix G.

Step 1: Estimation of a weighted average agglomeration elasticity value

As there are no agglomeration elasticity estimates for the Melbourne metropolitan area (PricewaterhouseCoopers, 2008), the agglomeration elasticities from DfT (2009) and NZTA (2008) were used in this research.

Both sources provide agglomeration elasticities for various industries – see Appendix G for details. These elasticities were used to estimate a weighted average elasticity value for Melbourne CBD using the employment share of each sector in the CBD as weights - the employment data was taken from CLUE (City of Melbourne, 2006). These are presented in Table 8.12. It is observed from Table 8.12 that the weighted elasticity value estimated for the CBD based on NZTA (2008) is twice that based on DfT (2009).

Table 8.12: Weighted average agglomeration elasticity value (ρ) for Melbourne CBD[37]

Sources	Weighted average agglomeration elasticity value
DfT (2009)	0.07
NZTA (2008)	0.14

Source: Developed from DFT (2009), NZTA (2008) and CLUE (2006).

Step 2: Estimation of the weighted average generalised cost of travel

The weighted average generalised cost of all trips ($AGC^{S}_{CBD-Mel}$) across metropolitan Melbourne to Melbourne CBD in the AM peak was estimated using outputs from MITM based on Equation 8.14.

$$AGC^{S}_{CBD-Mel} = \sum_{m} D^{S,m}_{CBD-Mel} GC^{S,m}_{CBD-Mel} \Big/ \sum_{m} D^{m}_{CBD-Mel} \qquad \text{(Equation 8.14)}$$

where

- $GC^{S,m}_{CBD-Mel}$ is the average generalised cost of travel (from MITM)
- $D^{S,m}_{CBD-Mel}$ is the total demand on mode *m* for travel across metropolitan Melbourne to the CBD (from MITM)
- S is the Base Case or Option scenario (i.e. a 10% rail capacity constraint)
- m is the mode of travel i.e. private auto or public transport (PT) mode.

The PETE method works out the average generalised cost of travel on each mode for each origin-CBD pair. Instead of doing so, this assessment simplified the computation by estimating an average $GC^{S,m}_{CBD-Mel}$ value for the private and PT mode across all origins of various distance bands from Melbourne CBD weighted according to their travel demands.

NZTA (2008) highlighted that the weights ($D^{S,m}_{CBD-Mel}$) need to be identical for the Base Case and option scenarios; however no such conditions were specified by DfT (2009). This research adhered strictly to the weights requirement specified by each method. The estimated weighted average generalised costs of travel into the CBD are shown in Table 8.13. In this instance, it is observed that the weighted average generalised cost estimated using the NZTA's (2008) approach is lower than that based on DfT (2009).

[37] The corresponding ρ values for Inner Melbourne region estimated using the same approach and employment data from ABS (2006f) is 0.069 – 0.134. This is close to the CBD values shown in Table 8.12.

Consultation with both DfT and NZTA[38] suggested that that the slight variation in their approaches may be due to their minor differences in the interpretation of Graham's (2005, 2006a, 2006b, 2007b) work. However, it appears from this assessment that the slight variation in their weights requirement is probably to compensate for their differences in the elasticity values - it is observed that while the NZTA's (2008) agglomeration elasticities are higher than DfT's (2009), they compensate the higher elasticities by using identical travel demands (i.e. $D^{S,m}_{CBD-Mel}$) which yielded lower estimates of the average generalised cost of travel – see Table 8.13.

Table 8.13: Weighted average generalised cost of CBD trips (AM peak) for Base Case and Option scenario (i.e. a 10% rail capacity constraint) – based on MITM output[39]

		CBD	
		Auto mode	**PT mode**
Base Case	Total demand (trips)	12,850	98,850
	Average generalised cost / trip	$18.00	$13.79
	Weighted average generalised cost / trip	**$14.27**	
Option scenario – <u>different</u> weights; DfT's (2009) approach	Total demand (trips)[40]	14,780	93,340
	Average generalised cost / trip	$18.68	$13.79
	Weighted average generalised cost / trip	**$14.46**	
Option scenario – <u>identical</u> weights; NZTA's (2008) approach	Total demand (trips)	12,850	98,850
	Average generalised cost / trip	$18.68	$13.79
	Weighted average generalised cost / trip	**$14.35**	

[38] Obtained via personal communication.

[39] Estimates based on MITM's outputs suggest that there is no significant difference in the generalised costs for Inner Melbourne region under the Base Case ($14.27) and option scenarios as compared to CBD trips for both DfT ($14.46) and NZTA ($14.34). This is not surprising since all CBD bound traffic would have to go through Inner Melbourne region and the region is only a few kilometres larger than the CBD in terms of radii – see Figure 4.2. With similar weighted agglomeration elasticites (see footnote 37) and average generalised costs, it is reasonable to expect the CBD's productivity loss under an urban rail constraint to be of the same magnitude as Inner Melbourne region.

[40] The PT demand for the DfT (2009) approach was estimated outside MITM by reducing the train demand into CBD (from MITM) by 10% and assuming that 18% of the affected rail commuters switch to trams and buses (as based on HLB (2003); the automobile demand was generated by MITM based on the highway assignment conducted as outlined in Section 5.4.

Step 3: Estimation of the productivity loss

The average generalised costs of travel derived in step (2) were used to estimate the degeneration in the effective employment densities for Melbourne CBD due to a 10% rail capacity constraint in the AM peak. Based on DfT's (2009) and NZTA's (2008) definition, the effective employment density (ED^{S}_{CBD}) in this instance measures the accessibility of all workers in metropolitan Melbourne to firms in the Melbourne CBD based on the functional form shown in Equation 8.15.

$$ED^{S}_{CBD} = \frac{E^{S}_{Mel}}{AGC^{S}_{CBD-Mel}} \qquad \text{(Equation 8.15)}$$

where

- E^{S}_{Mel} is the total employment in metropolitan Melbourne in the scenario *S*
- $AGC^{S}_{CBD-Mel}$ is the average generalised cost of travel in the AM peak from metropolitan Melbourne to Melbourne CBD in the scenario *S*
- S is the Base Case or Option scenario (i.e. a 10% rail capacity constraint).

Equation 8.16 estimates the productivity loss to the CBD due to dis-agglomeration associated with a 10% rail capacity constraint.

$$\delta PR_{CBD} = \left(\frac{ED^{Option}_{CBD}}{ED^{BaseCase}_{CBD}}\right)^{\rho} - 1 \qquad \text{(Equation 8.16)}$$

where

- δPR_{CBD} is relative reduction in the CBD's productivity
- ρ is the weighted average agglomeration elasticity presented in Table 8.12.

As the total employment in metropolitan Melbourne for both the Base Case and the Option scenario is not expected to fluctuate for a particular time period, Equation 8.16 can be re-written as Equation 8.17.

$$\delta PR_{CBD} = \left(\frac{AGC^{BaseCase}_{CBD}}{AGC^{Option}_{CBD}}\right)^{\rho} - 1 \qquad \text{(Equation 8.17)}$$

The weighted average agglomeration elasticities shown in Table 8.12 and the respective weighted average generalised cost of travel presented in Table 8.13 were then inputted into Equation 8.17 to estimate the productivity shocks. These are presented in Table 8.14 - to recap, a positive shock represents a productivity deterioration.

Table 8.14: Productivity shocks (associated with a 10% rail capacity constraint) for Melbourne CBD

Sources	Productivity shocks
DfT (2009)	0.09%
NZTA (2008)	0.08%

As shown in Table 8.14, the productivity shocks for Melbourne CBD estimated based on DfT's (2009) and NZTA's (2008) method and their respective agglomeration elasticities are very close in value. This is reasonable since both methods and their respective elasticities were based on the same work of Graham (2005, 2006a, 2006b, 2007b) and the productivity shocks were estimated for the same CBD. The above outcome appears to support the earlier proposition that the slight variation in the way that DfT (2009) and NZTA (2008) estimate the weighted average generalised cost of travel ($AGC^{S}_{CBD-Mel}$) is to offset the differences in their agglomeration elasticity values.

For sensitivity analysis, this research estimated the range of productivity shocks using DfT's (2009) agglomeration elasticities with identical travel demand weights and vice versa with the elasticities from NZTA (2008). The agglomeration elasticities from Graham (2006b) were also used in the analysis with both identical and varied weights. The sensitivity tests yielded a very wide range of productivity shocks between 0.04% - 0.30%. It appears from the wide range of shock values that it may not be meaningful to switch the weight requirement of DfT (2009) and NZTA (2008).

8.5.2 Application of Productivity Shocks on TERM

The productivity shocks shown in Table 8.14 were applied directly on the Inner Melbourne region in TERM for both SR and LR simulations. The differences between the SR and LR simulations lie in the timescale assumptions. As highlighted in Horridge (2003, page 58), the timescale is not explicit in CGE modelling. Dixon et al. (1982, page 65) suggests that the simulation timescale is generally considered as the period of time that would be needed for economic variables to adjust to a new equilibrium. They explain that the SR effects are measured by the change in the equilibrium values of variables in a situation of fixed, industry-specific capital stocks while in LR simulations, ORANI allows the capital stock level to adjust. Horridge (2003, page 58) highlighted that "a SR is usually thought to be between 1 and 3 years".

As per the other ORANI-style CGE models, the following key assumptions underlie the short and long term simulations in TERM.

1. Short-run (SR) simulations

- Capital stocks are held fixed since they would take sometime to install and hence are unlikely to be affected.
- Real-wages are assumed to remain unchanged given the rigidities in the labour market.

2. Long-run (LR) simulations

- In most LR simulations, capital stocks are free to adjust in such a way that maintains the rates of return (which is set by the world interest rate) and aggregate investment follows the aggregate capital stock. However, as explained in Section 8.3.2.3, the capital stock and investment are fixed nationally in this exercise so as to ensure the compositional changes will not cause any perverse results at the macro economic level.
- Aggregate employment is held constant and the real wage adjusts – this is to be consistent with the argument that the labour market and unemployment rate are determined by mechanisms outside the model in the LR.
- Household and government expenditures move in tandem.

8.6 TERM Output

8.6.1 Overview

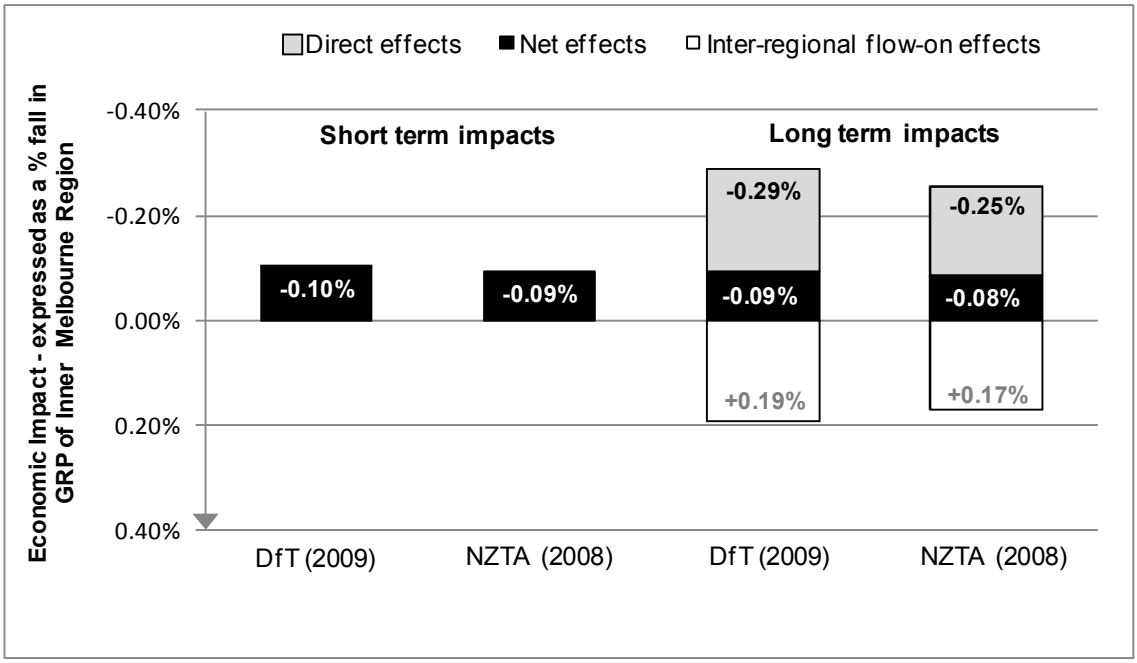
The economic values of the productivity shocks shown in Table 8.14 estimated by TERM for the SR and LR are summarised in Figure 8.7. To facilitate the presentation of TERM's results, the economic impacts are classified as follows.

1. **Direct effects** -
   These refer to the intra-regional impacts on the Inner Melbourne region only i.e. the effects on the region itself. The impacts are expressed as a percentage fall in the GRP of Inner Melbourne region.

2. **Inter-regional flow-on effects** -
   These refer to the impacts on the other region's economies that arise from the initial shock on Inner Melbourne region. These inter-regional flow-on effects are estimated by summing the GRP impacts on the other regions (in absolute terms) and expressed as a percentage of the Inner Melbourne region's GRP.

3. **Net effects** -
   The net effects are overall effect on the nation. In other words, they are the summation of both the direct and inter-regional flow-on effects across all regions. This is also expressed as a percentage of the Inner Melbourne region's GRP.

The x-axis indicates the sources of agglomeration elasticities that the productivity shocks were derived from. The first two columns from the left represent the SR results – one from each productivity shock based on the agglomeration elasticities from DfT (2009) and NZTA (2008). The 3rd and 4th columns represent the LR results from the two sources respectively.



Note: For the short term results, the net effects are essentially the direct impacts to the Inner Melbourne region as the flow-on effects in the short term was estimated to be negligible. See next section for more details.

Figure 8.7: Economic impacts associated with a 10% rail capacity constraint - expressed as a percentage change in Inner Melbourne region's GRP

Figure 8.7 suggests that a 10% rail capacity constraint in the AM peak is associated with direct agglomeration dis-benefits valued at -0.09% to -0.10% of Inner Melbourne region's GRP in the SR. The inter-regional flow-on effects in the SR are, however, found to be negligible. Therefore, in the SR, the net effects are effectively the direct effects on Inner Melbourne region.

The direct effects on Inner Melbourne region in the longer term are found to be more significant at -0.25% to -0.29% of its GRP. While the SR inter-regional flow-on effects are found to be negligible, the LR flow-on effects are estimated to have an equivalent value of +0.17% to +0.19% of the Inner Melbourne region's GRP. The significant and positive flow-on effects on the other regions in the LR essentially brings the overall LR net agglomeration dis-benefits on the nation to almost the same level as the short term.

So what are these inter-regional flow-on effects and why do they differ in the short and long term? The following section examines TERM's results in more details with focus on the mechanism underlying the inter-regional flow-on effects.

8.6.2 Short-Run Economic Impact

This section reports the SR macro results for the productivity shocks shown in Table 8.14. Given that TERM's output based on both the productivity shocks shown in Table 8.14 are very similar, this section concentrates on the detailed results based on the productivity shock estimated using DfT's (2009) agglomeration elasticity and method i.e. productivity deterioration of 0.09%.

Table 8.15 reports the macro results from TERM for all regions for the productivity shock of 0.09% on Inner Melbourne region[41] in the SR. The figures shown in Table 8.15 represent the percentage changes in each macro variable.

Table 8.15: Macro results from TERM for a SR productivity shock of 0.09% on Inner Melbourne region - shown as a percentage change in variable[42]

MainMacro	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA	Australia as a whole
1 Real Household Consumption	-0.048	-0.002	-0.002	-0.002	-0.001	-0.002
2 Real Investment	-0.077	-0.001	-0.002	-0.002	-0.001	-0.002
3 Real Government Consumption	0.000	0.000	0.000	0.000	0.000	0.000
4 Total Exports	-0.025	-0.004	-0.003	-0.001	0.000	-0.002
5 Total Imports	-0.011	-0.009	-0.006	-0.003	-0.003	-0.002
6 Trade Balance	-0.018	-0.006	-0.004	-0.002	-0.001	0.000
7 Real GRP / GDP	-0.102	0.000	0.000	0.000	0.000	-0.002
8 Aggregate Employment	-0.022	0.001	0.000	0.000	0.000	0.000
9 Aggregate Capital Stock	0.000	0.000	0.000	0.000	0.000	0.000

Note: At regional level, total exports include both regional and international exports. Similarly, at the regional level, total imports include both regional and international imports. However, at the national level, only international trade is included. Thus, for rows 4 and 5, column 7 is not a weighted sum of the first 6 columns.

[41] The SR macro results for the productivity shock (0.08%) based on NZTA's (2008) values show similar trends.

[42] Table 8.15 is presented in 3 decimal places as the percentage change in majority of the variables would not be visible if the figures are represented in 2 decimal places. For consistency, only the BOTE results are presented in 3 decimal places.

Prior to examining the macro results for Inner Melbourne region, a BOTE analysis was carried out using the national results to assess whether the model is behaving reasonably. A good BOTE model for this is Equation 8.18.

$$y = a + S_k k + S_l l \qquad \text{(Equation 8.18)}$$

where

- *y* is the percentage change in the Gross Domestic Product (GDP) of Australia
- *a* is the percentage change in the technological variable nationally caused by the productivity deterioration in Inner Melbourne region
- *k* is the percentage change in capital inputs nationally
- *l* is the percentage change in labour inputs nationally
- S_k *and* S_l are the capital and labour shares in primary factor costs.

Information from TERM suggests that the Inner Melbourne region contributes about 1.75% to the overall GDP of Australia. As shown in Table 8.15, there is no change in the aggregate capital nationally and a very small change (of -0.00025%) in national employment in the SR. Hence, a productivity deterioration of 0.09% in Inner Melbourne region is envisaged to "value-add" about -0.002% (=1.75%*-0.09%) to the Australian GDP. This equal to the -0.002% fall in Australia's GDP estimated in Table 8.15 which suggests that the model is behaving reasonably.

8.6.2.1 Direct Effects

Moving on to the macro results for Inner Melbourne region, recall from Equation 8.13 that, with the real wage fixed and little movement in P/P_c in Inner Melbourne region, an increase in *A* (which represents a technological deterioration) leads to a decrease in employment. Table 8.15 suggests that the drop in the Inner Melbourne region's productivity in the SR causes a 0.022% reduction in its labour demand – see row 8 of Table 8.15. As the Inner Melbourne region's employees come from all regions (as reported in Section 8.3.2.1), this reduction in the Inner Melbourne region's labour demand contributes negatively to real household income[43] for all regions due to a loss of labour income, although outside of Inner Melbourne region the impact on household income is small.

[43] The fall in household income is not shown explicitly in Table 8.15. However, household consumption, which is shown in Table 8.15, is directly link to household income. See Equation E51 in Appendix E.

A BOTE analysis was carried out using Equation 8.18 to identify the supply-side determinants of the effects on Inner Melbourne region's GRP. In the SR, *k* = 0 since capital stocks are held constant (see row 9 of Table 8.15). Based on primary cost information from TERM, S_k and S_l are estimated to be 0.4 and 0.6 respectively. Since *a* fell by just over -0.09% and L dropped by -0.022%, the BOTE analysis using Equation 8.18 estimated the following drop in the GRP of Inner Melbourne region.

$$y = a + S_k k + S_l l$$

= -0.094% + 0.6*-0.022%

= -0.107%

This is exactly equal to TERM's result for Inner Melbourne region's GRP at <u>factor cost</u>. The GRP result shown in Table 8.15 (row 7) is for GRP at <u>market prices</u> and is equal to -0.102%. The difference between the two is due to the small effects on indirect taxes which form a wedge between GRP at factor cost and GRP at market prices. Thus, it can be seen that the major contribution to the fall in Inner Melbourne region's GRP comes directly from the productivity deterioration, with the decline in Inner Melbourne region's employment adding 0.013% to the results for GRP at factor cost.

Corresponding to the real wage equation 8.13, the real rental equation derived from profit maximization is as shown in Equation 8.19.

$$\frac{Q}{P_i} = (\frac{P}{P_i}) * \frac{1}{A} * F_K(\frac{K}{L}) \qquad \text{(Equation 8.19)}$$

where

- *Q* is the rental price of capital
- P_i is the asset price of capital (investment price index)
- $F_K(K/L)$ is the derivative of *F* with respect to *K*.

Note that $F_K(K/L)$ is a decreasing function of *K/L* (i.e. as labour becomes scarce, so that *K/L* increases, the productivity of *K* decreases). Recall that in Section 8.4.1.1, it was shown that the decline in productivity cause a SR decrease in employment. Consequently with fixed capital, *K/L* increases, so that $F_K(K/L)$ must decrease.

With A increasing and little change in P / P_i, Q / P_i must fall for Equation 8.19 to remain in equilibrium. Thus, there is a lowering of the rate of return on capital, which in turn gives rise to a drop in investment. This is evident in row 2 for the Inner Melbourne region column in Table 8.15.

Since the ownership of capital and investment is spread across residents of various regions, the drop in rental income will also negatively affect household incomes of all regions to various extents. With the lower income from labour and from capital and land rental, Inner Melbourne region is estimated to lower its household consumption by 0.048% (see Table 8.15). The negative effect on the income of regions, resulting from their provision of labour and ownership of capital and land in Inner Melbourne region, results in a small fall in their regional consumption despite a zero effect on their GRP at the third decimal place.

The drop in the productivity of primary factors would essentially translate to a higher cost of production in the Inner Melbourne region. This causes the Inner Melbourne region's exports to become less competitive which results in a drop in its export volume. On the other hand, the lost of competitiveness also causes domestic prices (of intermediate goods and services) to increase relative to import prices. This induces a substitution towards imported goods and services from other regions. However, the fall in income of the region causes a drop in the consumption of imports. Between the two forces, the latter is the dominant effect and therefore the overall import into Inner Melbourne region falls by -0.011% (see row 5 of Table 8.15). Overall, these forces bring about a -0018% fall in the balance of trade (or net exports) for Inner Melbourne region (see row 6 of Table 8.15).

The GRP of a region is measured by the sum of the region's household consumption expenditure, investment, government consumption expenditure and its balance of trade (McTaggart et al., 2007). Therefore, the percentage change in the GRP of a region ($\Delta grp\%$) can be represented by Equation 8.20:

$$\Delta grp\% = S_c{*}c + S_i{*}\, i + S_g{*}g + S_x{*}\, x - S_m{*}m + S_{nm}{*}Nm \qquad \text{(Equation 8.20)}$$

where

- c is the percentage change in the region's household consumption
- i is the percentage change in region's investment
- g is the percentage change in regional government's expenditure

- x is the percentage change in the total exports (i.e. regional plus international exports) for the region
- m is the percentage change in the total imports (i.e. regional plus international imports) for the region
- Nm is the percentage change in the net margins for the regions. Net margins refer to the net inter-regional exports of services for used as margins – see Section 8.2.2.7 for explanation on margins)
- S_c, S_i, S_g, S_x, S_m, and S_{nm} are the GRP shares of the respective components.

Based on Inner Melbourne region's GRP information from TERM, S_c, S_i, S_g, S_x, S_m, and S_{nm} were estimated to be 0.565, 0.187, 0.154, 4.604, -4.300 and -0.208 respectively. Following Equation 8.20, the GRP change for Inner Melbourne region is estimated to be:

$$\Delta grp\% = S_c*c + S_i*i + S_g*g + S_x*x - S_m*m + S_{nm}*Nm$$

$$= (0.565*-0.048\%) + (0.187*-0.077\%) + (0.154*0) + (4.604*-0.025\%) + (-4.300^{44}*-0.011) + (-0.208*-0.038)$$

$$= -0.102\%.$$

This is equal to the -0.102% fall in GRP shown in row 7 of Table 8.15. It can be seen that the major contribution to the fall in Inner Melbourne region's GRP comes from the fall in export volume. Overall, the productivity deterioration of -0.09% is expected to cause a -0.102% fall in the GRP of Inner Melbourne region – this is the result summarised in Figure 8.7.

[44] The negative sign for S_m in Equation 8.20 is incorporated into its GRP share.

8.6.2.2 Inter-Regional Flow-On Effects

The fall in the income of households in the other regions leads to their consequential reduction in consumption and investments (as shown in row 1 and 2 of Table 8.15). In addition, affected by their input-output linkages[45] to the firms in the Inner Melbourne region, the other regions within Victoria State also see a fall in their export volumes. While their import volumes also decrease (due largely to a fall in their overall consumption), a larger import volume means that these other regions in Victoria State still see a trade deficit.

On the other hand, the RoA sees a slight increase of +0.0004% in its exports. This suggests that the goods and services imported to Inner Melbourne region and the other regions within Victoria State are from the RoA region as well as foreign imports. While the import volume into RoA falls but a larger import volume (compared to export) means that the RoA region still sees a negative balance of trade. The impacts on the various economic agents in the other regions are components of the inter-regional flow-on effects. Collectively, these effects will impact upon the GRP of the other regions as suggested by Equation 8.20.

The macro results shown in Table 8.15 suggest that the productivity deterioration in Inner Melbourne region essentially causes a drop in the GRP of all other regions except the Middle Melbourne region which sees a slight increase in its employment (+0.001%) and GRP (+0.0003%). This is due to the competitive effects where the surplus labour supply from the Inner Melbourne region essentially flows into the Middle Melbourne region which has the closest industrial structure. This is consistent with the assessment carried out in Section 4.2.2 – Section 4.2.2 suggests that some of the knowledge-based firms in the Inner Melbourne region (in particular the CBD) may have spilled over or relocated into the surrounding areas within 10km from the CBD, which would include the Middle Melbourne region.

While the other regions' GRP fall as a result of the productivity deterioration in Inner Melbourne region, the gains in Middle Melbourne region (in absolute terms) is sufficient to negate the negative effects on the other regions. Table 8.16 explains this further.

[45] The firms in the other regions within Victoria State may use intermediate goods and services provided by the Inner Melbourne region of which the prices have increased when the productivity of Inner region deteriorates. This causes the exports of the other regions within Victoria State to be less competitive.

Table 8.16: Estimation of inter-regional flow-on effects in the SR for productivity shock of 0.09% - output from TERM

	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Real GRP ($ million) - from TERM database	16893.0	83816.1	70257.8	59892.4	732299.3
Real GRP impact (%) - output from TERM	-0.1015	0.0003	-0.0002	-0.0003	0.0000
Real GRP impact ($ million)	-1714.8	26.8	-16.9	-15.0	0.0
Inter-regional Flow-on effects ($million)		**-5.014**			
Inter-regional Flow-on effects (% of Inner Mel GRP)		**-0.0003**			

As shown in Table 8.16, arising from the 0.09% productivity deterioration in Inner Melbourne region, the GRP gain in Middle Melbourne region in the SR is about $26.8 million as shown by TERM's output. On the other hand, TERM estimated that the Outer Melbourne, RoV and RoA regions lost a total of $31.8 million in their GRP. The total inter-regional flow-on effects is therefore about -$5 million. This is equivalent to a 0.0003% fall in Inner Melbourne region's GRP (value of about $16.9 billion as estimated based on data from TERM) which is not significant.

8.6.2.3 Net Effects on the Nation

As shown in Table 8.16, the SR inter-regional flow-on effects are not substantial. Therefore, the net effect on the nation of the productivity shock is essentially the direct impact on Inner Melbourne region.

8.6.2.4 Impact on Various Sectors

The macro results suggest that there is a -0.022% drop in the labour demand of Inner Melbourne region due to the productivity deterioration of 0.09%. Table 8.17, which is based on data extracted from TERM, shows the distribution of possible employment lost across the sectors within the Inner Melbourne region due to this productivity deterioration.

Table 8.17: Possible employment lost from each sector within Inner Melbourne region for SR productivity shock of 0.09% - output from TERM

	1 % change in labour	2 Total no. of jobs	3 Total wage bills ($mil)	4 wage rates ($mil)	5 Relative wage	6 % contribution to employmt drop - wgted by no. of jobs	7 Shares of employmt lost (%) - wgted by no. of jobs	8 % contribution to employmt drop - wgted by wage bill	9 Shares of employmt lost (%) - wgted by wage bill
Primary	-0.017	805	35.53	0.04	0.74	0.000	0.55	0.000	0.32
FoodDrinks	-0.018	1,420	84.25	0.06	1.00	0.000	1.01	0.000	0.79
OthManufact	-0.030	11,482	575.02	0.05	0.84	-0.002	13.62	-0.002	8.97
Utilities	-0.021	1,079	66.94	0.06	1.05	0.000	0.90	0.000	0.73
Construction	-0.025	4,927	180.43	0.04	0.62	-0.001	4.97	-0.001	2.39
Trade	0.022	20,494	867.23	0.04	0.71	0.003	-18.30	0.002	-10.18
HotelsCafes	**-0.027**	**12,049**	**205.68**	**0.02**	**0.29**	**-0.002**	**12.97**	**-0.001**	**2.91**
RoadTransprt	0.029	1,093	45.30	0.04	0.70	0.000	-1.30	0.000	-0.71
RailTransprt	-0.014	202	15.26	0.08	1.27	0.000	0.11	0.000	0.11
OtherTrans	-0.033	977	75.55	0.08	1.30	0.000	1.30	0.000	1.32
WaterTrans	-0.009	139	9.07	0.07	1.10	0.000	0.05	0.000	0.04
AirTransport	-0.033	1,287	58.87	0.05	0.77	0.000	1.70	0.000	1.02
Communicatn	-0.023	2,907	202.37	0.07	1.17	0.000	2.66	-0.001	2.43
BankInsure	-0.025	11,744	1,073.83	0.09	1.54	-0.002	12.02	-0.003	14.45
OwnerDwellng	-0.010	0	1.03	0.00	0.00	0.000	0.00	0.000	0.01
BusSrvces	**-0.037**	**21,411**	**1,825.12**	**0.09**	**1.44**	**-0.005**	**32.13**	**-0.008**	**36.01**
TechServic	**-0.074**	**12,750**	**989.21**	**0.08**	**1.31**	**-0.006**	**38.02**	**-0.008**	**38.78**
GovAdminDef	-0.040	7,523	338.71	0.05	0.76	-0.002	11.96	-0.002	7.08
EducHealth	0.012	25,354	1,421.32	0.06	0.94	0.002	-12.56	0.002	-9.26
ChldCommCare	0.079	1,911	42.13	0.02	0.37	0.001	-6.08	0.000	-1.76
OthServices	-0.014	7,848	634.28	0.08	1.36	-0.001	4.27	-0.001	4.54
Total		**147,403**	**8,747.11**	**0.06 (ave)**		**-0.017**	**100.00**	**-0.022**	**100.00**
Explanation	extracted from TERM			= (3)/(2)	= (4)/ave(4)	= [(1)*(2)]/Tot (2)	= (6)/ Tot(6)	= [(1)*(3)]/Tot (3)	= (8)/Tot(8)

Note: The last row explains the arithmetic to calculate each column.

The loss of productivity causes a reduction in the employment in Inner Melbourne region. Employment could be measured in two ways – in terms of the number of jobs or in terms of wage bill units. When employment is measured in wage bill units, each job is weighted by the income it earns in that job. As shown in Table 8.15, the aggregate level of employment lost in Inner Melbourne region measured in terms of wage bill units is 0.022% which is the value reflected in Table 8.15 (row 8). The fall in employment measured in terms of number of jobs is 0.017% (column 6 of Table 8.17).

As shown in Table 8.17, the biggest source of employment losses occur in the Business Services and the Technical Services sectors (shown highlighted). TERM's output suggests that these 2 sectors (compared to the other industries) sell the highest proportion of their outputs to the other regions. Therefore, when the productivity in the Inner Melbourne region deteriorates, they suffer the most from competitive effects from the other regions.

While the percentage change in labour demand for Technical Services sector is about twice that for the Business Services sector, the latter has a total employment size double that of the former. That is why they both end up with similar shares of the employment losses. The Technical Services sector contributes about 38% of the job losses. However, based on the wage bill unit measure, the sector's contribution to employment lost is marginally higher at 39%. They differ because employees in the Technical Service sector have relatively higher wages – see relative wage on Column 5 of Table 8.17.

The other big contributor, the Business Services sector, accounts for 32% of the job losses in Inner Melbourne region. However, this sector contributed 36% in the labour input for loss of labour earning power in Inner Melbourne region. The reason is because it is a high paying sector, with a relatively high wage of 1.44 – i.e. the sector's average wage is about 44% higher than the average wage across all sectors in the Inner Melbourne region.

Another significant contributor to employment lost in the region is the Hotel and Cafes sector (shown highlighted). As shown in Table 8.17, this sector accounts for some 13% of the job losses in Inner Melbourne region in the short term when its productivity deteriorates. However, the sector's contribution to employment lost is much lower (less than 3%) based on the wage bill unit measure. The reason is that the employees in this sector have relatively low wages of 0.29. This is consistent with the survey results as reported in Section 6.3.2 (Figure 6.6) – the highest number of employers in this sector predicted that the rising rail congestion will have an impact on their short-term employment plans.

Table 8.17 shows that the Trade, Education and Healthcare as well as the Childcare sectors within Inner Melbourne region are expected to see an increase in their employment when the overall productivity level of the region deteriorates. The outputs from these sectors are less affected by the competitive effects from the other regions since most of their products and services are consumed locally within Inner Melbourne region. Therefore, although their total output falls, a larger drop in their productivity that these sectors would need more employees when the productivity of Inner Melbourne region deteriorates. Having said so, the employment gains in these sectors may, however, be over-estimated given their over-representation in TERM.

Table 8.17 (column 5) shows that the Trade, Education and Healthcare as well as the Childcare sectors are relatively low paying industries. This suggests that the gains in the employment of these industries could be due to an increase largely in non-professional workers that lost their jobs in the other sectors. This is consistent with the findings of the CBD employers' survey (Section 6.3.1 and 6.3.2), which concluded that lower-skilled workers have a higher level of employment mobility as their less specialised skill set means that these workers are able to find employment elsewhere. In addition,

8.6.3 Long-Run Economic Impact

Similar to the SR results, the discussion on the LR macro results also concentrates on the detailed results based on the productivity shock estimated using DfT's (2009) agglomeration elasticity and method i.e. productivity deterioration of 0.09%.

The LR results are more difficult to interpret at the regional level since both labour and capital are mobile. Therefore, as explained in Section 8.3.2.5, two additional equations are activated for the LR simulations so as to tie down aggregate capital stock and investment nationally, while allowing them to move across the various regions in TERM. This is to enable a better understand of the LR results since any national GDP impact can be totally attributed to the productivity shock on Inner Melbourne region[46].

Table 8.18 presents the macro results from TERM for all regions for the productivity shock of 0.09% on Inner Melbourne region in the long term[47]. As with Table 8.15, the results shown in Table 8.18 are in percentage change term for each macro variable.

[46] There is another important reason for these assumptions. With the supply of factors held fixed at the national level and all expenditure-side aggregate components of GDP except household consumption held constant, movements in national real consumption can be used as an indicator of the effects on national economic welfare.

[47] The LR macro results for the productivity shock (0.08%) based on NZTA's (2008) values show similar trends.

Table 8.18: Macro results from TERM for LR productivity shock of 0.09%
- shown as a percentage change in variable

MainMacro	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA	Australia as a whole
1 Real Household Consumption	-0.105	-0.014	-0.009	-0.005	0.001	-0.003
2 Real Investment	-0.222	-0.010	-0.009	-0.003	0.006	0.000
3 Real Government Consumption	0.000	0.000	0.000	0.000	0.000	0.000
4 Total Exports	-0.070	-0.017	-0.017	-0.006	0.006	-0.002
5 Total Imports	-0.026	-0.029	-0.019	-0.008	-0.006	-0.002
6 Trade Balance	-0.049	-0.023	-0.018	-0.007	0.000	0.000
7 Real GRP / GDP	-0.288	-0.006	-0.007	-0.002	0.006	-0.002
8 Aggregate Employment	-0.203	-0.003	-0.005	-0.001	0.006	0.000
9 Aggregate Capital Stock	-0.223	-0.008	-0.008	-0.003	0.006	0.000

Note: At regional level, total exports include both regional and international exports. Similarly, at the regional level, total imports include both regional and international imports. However, at the national level, only international trade is included. Thus, for rows 4 and 5, column 7 is not a weighted sum of the first 6 columns.

As per the SR evaluation, prior to examining the LR macro results for Inner Melbourne region, a BOTE analysis was carried out using the national results to assess whether the model is behaving reasonably for the LR.

Recall that a 0.09% deterioration in Inner Melbourne region productivity translates into a 0.002% productivity fall at the national level. In the long run, *k* and *l* are both zero at the national level by assumption. Based on Equation 8.18, the Australian GDP falls by the same level as the national technological deterioration i.e. 0.002% at 3 decimal places (see row 7 last column of Table 8.18).

The remaining results in the last column of Table 8.18 can be explained with the aid of Equation 8.20 (see Section 8.6.2.1) which computes the percentage change in national GDP from the expenditure side. In our LR simulation, national investment, government expenditure and net trade are fixed. So, following from Equation 8.20, one would expect:

$$\Delta grp\% = S_c{*}c + S_i{*}\,i + S_g{*}g + S_x{*}\,x - S_m{*}m + S_{nm}{*}Nm$$

$\Delta gdp\% = S_c{*}c$ which means

$$c = \frac{1}{S_c} gdp\%$$

Information from TERM indicates that consumption share of GDP, S_c for Australia is about 0.567. Table 8.18 shows that Australia's GDP would change by -0.002% in the LR if the productivity of Inner Melbourne region deteriorates by 0.09%. Therefore,

c = (1/0.567)*(-0.002%) = -0.003%.

This is equal to the -0.003% fall in household consumption nationally as shown in Table 8.18 (row 1).

8.6.3.1 Direct Effects

Generally, the trend of the LR intra-regional impacts on Inner Melbourne region is broadly similar to the SR simulations. Comparing Tables 8.18 and 8.15, it can be seen that the magnitude in the decline in macro economics variables is considerably more substantial in the LR than the SR. While there are many reasons underlying the falls in the various components of the Inner Melbourne region's GRP that are common with those explained for the SR, there is one key difference which is explained in the next paragraph.

In the LR, the capital stock is only held fixed at the national level. This is unlike the SR where capital stock is held fixed at the regional industry level. It is can be seen from row 9 of Table 8.18 that the capital stock of the Inner Melbourne region decreases. The fall in Inner Melbourne region's capital stock can be explained using Equation 8.19 (see Section 8.6.2.1). In Equation 8.19, Q/P_i represents the rate of return. In the LR, capital will move between sectors and so there is hardly any movement in the rate of return i.e. there is only a small change in the rate of return (so as to keep aggregate capital unchanged at the national level). With P/P_i barely moving in the Inner Melbourne region, Equation 8.19 suggests that an increase in A (which represents a technological deterioration) would cause $F_K(K/L)$ to rise in the LR. But $F_K(K/L)$ is a decreasing function of K/L. Therefore, K/L decreases. As the demand for labour, L is decreasing, capital stock, K, must fall by a larger magnitude than L. Table 8.18 suggests that the drop in the Inner Melbourne region's productivity in the LR causes a 0.203% reduction in its labour demand while the capital stocks of Inner Melbourne region fall by -0.223% in the LR (see row 8 and 9 of Table 8.18).

A BOTE assessment based on Equation 8.18 was carried out to assess the major determinants of the TERM LR simulation results for the Inner Melbourne region. Based on primary cost information from TERM, it was estimated earlier that the capital and labour shares of primary factor costs are 0.4 and 0.6 respectively. Since the productivity fell by just over -0.09%, the BOTE analysis estimated the GRP of Inner Melbourne region to fall by the following magnitude.

$$y = a + S_k k + S_l l$$

=-0.094% + 0.6*-0.203% + 0.4*-0.223%

= -0.305%.

This is exactly equal to TERM's result for Inner Melbourne region's GRP at factor cost. The GRP result shown in Table 8.18 (row 7) is for GRP at market prices and is equal to -0.288%. The difference between the two is due to the small effects on indirect taxes as explained earlier.

To further ascertain whether the fall in the various components of GRP is reasonable, a BOTE analysis was carried out using Equation 8.20. Based on Inner Melbourne region's GRP information from TERM, S_c, S_i, S_g, S_x, S_m, and S_{nm} were estimated to be 0.565, 0.187, 0.154, 4.604, -4.300 and -0.208 respectively. Based on Equation 8.20, the GRP change for Inner Melbourne region is estimated to be:

$$\Delta grp\% = S_c*c + S_i*i + S_g*g + S_x*x - S_m*m + S_{nm}*Nm$$

= (0.565*-0.105%) + (0.187*-0.222%) + (0.154*0) + (4.604*-0.070%) + (-4.300[48]*-0.026) + (-0.208*-0.109)

= -0.288%

This is equal to the -0.288% value shown in row 7 of Table 8.18. It can be seen that the decrease in export volume is the major contributor to the fall in Inner Melbourne region's GRP. This -0.288% fall in Inner Melbourne region's GRP is the LR direct impact summarised in Figure 8.7. This is observed to be about 2.5 to 3 times higher than the SR direct effects.

[48] The negative sign for S_m in Equation 8.20 is incorporated into its GRP share.

8.6.3.2 Inter-Regional Flow-On Effects

The macro results from TERM indicate that in the LR, the productivity deterioration causes a fall in the employment and GRP of all the other regions, except for the RoA region. Why is this so? A productivity deterioration in Inner Melbourne region causes an increase in the primary factor cost of production in the region. The increase in cost causes a drop in the demand of primary factors in Inner Melbourne region. In the LR, capital and labour are fixed nationally. Therefore, for the surplus primary factors in Inner Melbourne region to be fully utilised, the price of capital rental and labour must fall nationally. Inner Melbourne region ends up producing less and loses more workers as well as capital and investments. The lower capital rental price and labour wages, on the other hand, benefits all the other regions. The resultant effects of these impacts are explained previously in Figure 8.6(c) where the fall in capital and labour price causes the marginal productivity curve of region 1 (which represents Inner Melbourne region) to shift further downwards; on the other hand, the lowering of capital rental essentially causes an upward movement of the marginal productivity curve of region 2 which represents the other regions.

However, while the other regions within Victoria State benefit from the lower capital and labour price, their gain is more than offset by the higher production cost in Inner Melbourne region through their purchases of intermediate goods and services produced in Inner Melbourne region. In addition, they are also selling fewer commodities to Inner Melbourne region whose economy is contracting due to the productivity deterioration. This explains why these other regions within Victoria State also see a fall in their GRP. Table 8.19, 8.20 and 8.21 explains this further.

Table 8.19 shows the percentages of intermediate goods and services consumed by each region that are purchased from other regions. As shown in this table, the regions within Victoria State purchases more intermediate goods and services from the Inner Melbourne region compared to the RoA region. For example, 2.4% of the intermediate goods and services used in Middle Melbourne region are produced in Inner Melbourne region; but only 0.3% of the of the intermediate goods and services used in RoA are produced in Inner Melbourne region.

Therefore, when the production costs of Inner Melbourne region goes up, the other regions within Victoria State that purchases more intermediate goods and services from Inner Melbourne region are also affected. This is evident from Table 8.20 which shows that the basic price of goods and services in all the other regions in Victoria State increases when the productivity in Inner Melbourne region deteriorates.

Table 8.19: Proportion of intermediate goods and services consumed in region r that are purchased from region d

Region (d) purchase from	Region of consumption (r)				
	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Inner Mel region	44.50%	2.40%	2.00%	1.40%	0.30%
Middle Mel region	19.50%	83.00%	6.90%	5.40%	1.10%
Outer Mel region	16.00%	5.10%	77.70%	5.70%	1.40%
RoV	9.40%	3.20%	4.40%	69.70%	1.90%
RoA	10.70%	6.40%	9.10%	17.80%	95.40%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

Table 8.20: Percentage changes in the basic price of commodities in each region

Industries	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Primary	0.073	0.000	-0.002	-0.002	-0.001
FoodDrinks	0.046	0.003	0.002	0.001	-0.002
OthManufact	0.057	0.004	0.003	0.001	-0.002
Utilities	0.088	0.004	0.003	0.000	-0.003
Construction	0.067	0.004	0.004	0.002	-0.002
Trade	0.084	0.004	0.004	0.002	-0.002
HotelsCafes	0.070	0.004	0.003	0.001	-0.002
RoadTransprt	0.078	0.004	0.004	0.002	-0.002
RailTransprt	0.084	0.005	0.004	0.002	-0.002
OtherTrans	0.081	0.005	0.004	0.002	-0.002
WaterTrans	0.046	0.004	0.003	0.002	-0.002
AirTransport	0.053	0.004	0.003	0.002	-0.002
Communicatn	0.085	0.004	0.003	0.002	-0.003
BankInsure	0.124	0.005	0.005	0.002	-0.003
OwnerDwelIng	0.114	0.004	0.003	0.001	-0.004
BusSrvces	0.095	0.006	0.005	0.003	-0.002
TechServic	0.093	0.005	0.005	0.003	-0.002
GovAdminDef	0.096	0.004	0.004	0.002	-0.002
EducHealth	0.117	0.004	0.003	0.001	-0.003
ChldCommCare	0.118	0.004	0.003	0.001	-0.003
OthServices	0.080	0.005	0.004	0.002	-0.002

Table 8.21 shows the percentages of intermediate goods and services produced by each region that are sold to the other regions. For example, Middle Melbourne region sold 5.4% of its intermediate goods and services to the Inner Melbourne region; but the RoA only sold 0.3% of its intermediate goods and services to the Inner Melbourne region. As shown in Table 8.21, those regions within Victoria State sell a higher volume of their intermediate goods and services to Inner Melbourne region compared to RoA. As Inner Melbourne region is producing less, their demand for intermediate goods and services from the other regions also falls. Therefore, those regions within Victoria State that accounts for a higher volume of the imports into Inner Melbourne region are also affected more.

Table 8.21: Proportion of intermediate goods and services produced in region r and sold to region d

Region (d) of consumption	Region of Production (r)				
	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Inner Mel region	63.80%	5.40%	5.00%	3.50%	0.30%
Middle Mel region	11.10%	75.10%	5.20%	3.80%	0.70%
Outer Mel region	8.30%	5.60%	71.50%	4.80%	0.90%
RoV	5.20%	3.80%	4.60%	66.00%	1.50%
RoA	11.70%	10.10%	13.60%	21.90%	96.70%
Total	100.00%	100.00%	100.00%	100.00%	100.00%

On the other hand, the RoA region, which has the least trade interaction with Inner Melbourne region compared to the other regions, is relatively lesser affected by the increase in primary factor costs of Inner Melbourne region. This is evident from Table 8.20 which reports that the basic price of goods and services into the RoA region actually falls when the productivity in Inner Melbourne region deteriorates. The lower prices in RoA are due to the lower cost of production given the lower labour and capital rental prices. Overall, the competitive effects outweigh the price effects and the RoA region sees a net gain from the lower capital and labour price.

The gain in the RoA region (in absolute terms) is significant and more than compensates the negative effects on the other regions within Victoria State. As shown in Table 8.22, TERM's output suggests that the GRP impact on the other regions arising from a 0.09% productivity deterioration in Inner Melbourne region in the long term is equivalent to about +0.19% of the Inner Melbourne region's GRP.

Table 8.22: Estimation of inter-regional flow-on effects in the LR for productivity shock of 0.09% - output from TERM

	Inner Mel region	Middle Mel region	Outer Mel region	RoV	RoA
Real GRP ($ million)	16893.0	83816.1	70257.8	59892.4	732299.3
Real GRP impact (%)	-0.2878	-0.0058	-0.0065	-0.0018	0.0059
Real GRP impact ($ million)	-4861.1	-486.8	-460.0	-105.7	4314.7
Inter-regional Flow-on effects ($million)		**3262.146**			
Inter-regional Flow-on effects (% of Inner Mel GRP)		**+0.1931**			

These flow-on effects to the other regions are important for LR evaluation since the economic benefits associated with a transit system may lag many years after implementation. Their significant magnitude (as suggested by TERM's output) makes it more crucial to consider them.

8.6.3.3 Net Effects on the Nation

As shown in Table 8.22, the LR inter-regional flow-on effects are substantial and have an equivalent value of +0.19% of Inner Melbourne region's GRP. Inclusion of these inter-regional flow-on effects bring the LR overall net effect on the nation to about -0.10% (=-0.29% + 0.19%). This is almost the same level as the SR simulation.

8.6.3.4 Impact on Various Sectors

The macro results indicate a -0.203% drop in the labour demand of Inner Melbourne region in the long term due to the productivity deterioration of 0.09%. Table 8.23, which is based on data extracted from TERM, shows the distribution of possible employment lost across the sectors within the Inner Melbourne region in the LR due to this productivity deterioration.

As shown in Table 8.23, the aggregate level of employment lost in Inner Melbourne region measured in terms of wage bill units is 0.203% which is the value reflected in Table 8.18 (row 8). The fall in employment measured in terms of number of jobs is 0.176% (column 6 of Table 8.23).

Table 8.23: Possible employment lost from each sector within Inner Melbourne region for LR productivity shock of 0.09% - output from TERM

	(1) % change in labour	(2) Total no. of jobs	(3) Total wage bills ($mil)	(4) wage rates ($mil)	(5) Relative wage	(6) % contribution to employmt drop - wgted by no. of jobs	(7) Shares of employmt lost (%) - wgted by no. of jobs	(8) % contribution to employmt drop - wgted by wage bills	(9) Shares of employmt lost (%) - wgted by wage bills
Primary	-0.275	805	35.53	0.04	0.74	-0.001	0.85	-0.001	0.55
FoodDrinks	-0.113	1,420	84.25	0.06	1.00	-0.001	0.62	-0.001	0.54
OthManufact	-0.175	11,482	575.02	0.05	0.84	-0.014	7.77	-0.012	5.68
Utilities	-0.275	1,079	66.94	0.06	1.05	-0.002	1.14	-0.002	1.04
Construction	-0.237	4,927	180.43	0.04	0.62	-0.008	4.51	-0.005	2.41
Trade	-0.039	20,494	867.23	0.04	0.71	-0.005	3.12	-0.004	1.93
HotelsCafes	-0.186	12,049	205.68	0.02	0.29	-0.015	8.63	-0.004	2.15
RoadTransprt	-0.001	1,093	45.30	0.04	0.70	0.000	0.00	0.000	0.00
RailTransprt	-0.119	202	15.26	0.08	1.27	0.000	0.09	0.000	0.10
OtherTrans	-0.317	977	75.55	0.08	1.30	-0.002	1.19	-0.003	1.35
WaterTrans	-0.115	139	9.07	0.07	1.10	0.000	0.06	0.000	0.06
AirTransport	-0.191	1,287	58.87	0.05	0.77	-0.002	0.95	-0.001	0.63
Communicatn	-0.295	2,907	202.37	0.07	1.17	-0.006	3.31	-0.007	3.36
BankInsure	**-0.318**	**11,744**	**1,073.83**	**0.09**	**1.54**	**-0.025**	**14.40**	**-0.039**	**19.23**
OwnerDwellng	-0.128	0	1.03	0.00	0.00	0.000	0.00	0.000	0.01
BusSrvces	**-0.337**	**21,411**	**1,825.12**	**0.09**	**1.44**	**-0.049**	**27.84**	**-0.070**	**34.66**
TechServic	**-0.309**	**12,750**	**989.21**	**0.08**	**1.31**	**-0.027**	**15.18**	**-0.035**	**17.20**
GovAdminDef	-0.165	7,523	338.71	0.05	0.76	-0.008	4.79	-0.006	3.15
EducHealth	-0.028	25,354	1,421.32	0.06	0.94	-0.005	2.76	-0.005	2.26
ChldCommCare	**0.066**	**1,911**	**42.13**	**0.02**	**0.37**	**0.001**	**-0.49**	**0.000**	**-0.16**
OthServices	-0.108	7,848	634.28	0.08	1.36	-0.006	3.26	-0.008	3.85
Total		**147,403**	**8,747.11**	**0.06 (ave)**		**-0.176**	**100.00**	**-0.203**	**100.00**
Explanation	extracted from TERM			= (3)/(2)	= (4)/ave(4)	= [(1)*(2)]/Tot (2)	= (6)/ Tot(6)	= [(1)*(3)]/Tot (3)	= (8)/Tot(8)

Note: The last row explains the arithmetic to calculate each column.

Again, the biggest sources of employment losses are the Business Services and Technical Services sectors. However, it is observed that their shares of job losses have fallen compared to the short term. In particular, the Technical Services sector sees its employment shares lowered by are about half of the SR impacts. The lower proportion of job losses in these sectors is because the shares of job losses in the other sectors have gone up for the LR – see Figure 8.8.

Figure 8.8 compares the percentage shares of the job losses in Inner Melbourne region for the SR and LR - this figure was developed based on column 7 of Tables 8.17 and 8.23. As shown in Figure 8.8, in the LR, all sectors across Inner Melbourne region except Childcare services see a fall in their employment. This is unlike the SR where the employment of the relatively low-paying sectors (such as Trade and Education and Healthcare) actually went up to absorb the surplus employment from the other sectors within Inner Melbourne region.

TERM's output suggests that the Childcare services industry is the sector in the Inner Melbourne region where the highest proportion (more than 95%) of its services is consumed locally within the region. The competitive effect from other regions on this sector is therefore very small. Thus, the fall in its productivity is larger than the drop in its output. This explains why this is the only sector that still sees an employment gain in the LR when the productivity deteriorates in Inner Melbourne region. For the other regions, the drop in their output outweighs the fall in their productivity.

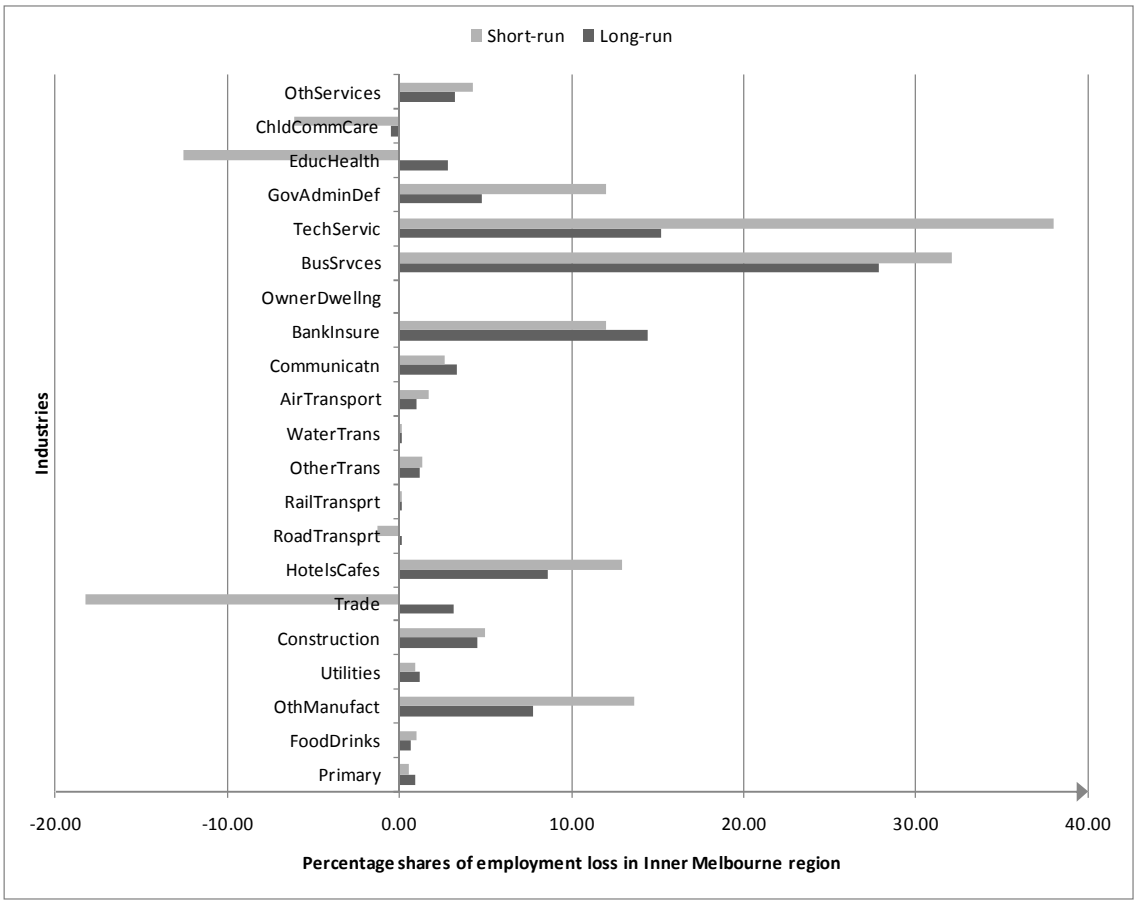


Figure 8.8: Percentage shares of job losses across the sectors in Inner Melbourne region for SR and LR

Another significant contributor to LR employment lost in Inner Melbourne region is the Banking and Insurance sector (shown highlighted in Table 8.23). As shown in Table 8.23, this sector accounts for some 14% of the job losses in Inner Melbourne region in the long term when its productivity deteriorates. However, the sector's contribution to employment lost is much higher (at 19%) based on the wage bill unit measure. The reason is that the employees in this sector have relatively high wages of 1.54 – i.e. the sector's average wage is about 54% higher than the average wage across all sectors in the Inner Melbourne region.

It is noted that the three biggest contributors to employment lost in the region in the long term also have the highest relative wages. Although the mechanism differs, this is consistent with earlier proposition from the survey that, in the longer term, more professional employees are moving out of the Inner Melbourne region and relocating to other major Australian cities to seek employment.

8.7 Summary

The aim of this chapter is to report the TERM modelling work that was carried out in this research. The TERM model was used in this research to explore how the agglomeration effects associated with urban passenger rail projects may percolate through the economy of Melbourne CBD (which is a subset of Inner Melbourne region) and the other regions in Australia.

The version of TERM used in this research disaggregated the Melbourne metropolitan area into three regions (Inner, Middle and Outer Melbourne region), while the other Victorian Statistical Divisions (SD) and all the SDs of the other five states were aggregated into two regions (RoV and RoA respectively). Melbourne CBD, which is the focus of this research, is incorporated into the Inner Melbourne region.

Modifications were made to the current TERM database so that household income for a region is earned from a weighted sum of regional locations of employment, with the weights being based on commuter travel patterns. Thus the model captures the effect on inter-regional household consumption of workers living in one region and working in another. This research also assumed that any associated dis-agglomeration effects affecting Melbourne CBD can be treated as the estimated regional impact on Inner Melbourne region so as to facilitate the TERM modelling.

As TERM contains no modelling of agglomeration economies, preliminary investigation was carried out to explore how to model agglomeration effects in TERM. The investigation concluded that it may be reasonable to simulate such effects by imposing a productivity shock in TERM. Agglomeration elasticities from secondary research were used to estimate a series of productivity shocks for the CBD associated with a 10% rail capacity constraint via the PETE method. These impacts were used to “shock” the *aprim* variable, which is a technical change variable that augments the productivity of all primary factors, for Inner Melbourne region in TERM in the SR and LR.

The TERM modelling outputs suggest that a 10% rail capacity constraint in the AM peak is associated with direct intra-regional agglomeration dis-benefits valued at -0.09% to -0.10% of Inner Melbourne region's GRP in the SR. The inter-regional flow-on effects to the other regions in the SR are found to be negligible.

The direct intra-regional effects in the LR are found to be more significant – about -0.25% to -0.29% of the Inner Melbourne region's GRP. While the SR flow-on effects are found to be negligible, the LR inter-regional flow-on effects are estimated to be equivalent to +0.17% to +0.19% of the Inner Melbourne region's GRP. The significant and positive flow-on effects on the other regions in the LR essentially bring the net agglomeration dis-benefits to the nation to almost the same level as the SR. TERM's results suggest that the flow-on effects to the other regions are important for LR evaluation since the economic benefits associated with a transit system may lag many years after implementation. Their significant magnitude (as suggested by TERM's output) makes it more crucial to consider them.

The results from TERM are compared against the agglomeration dis-benefits estimated using other approaches. The agglomeration dis-benefits estimated based on the various approaches are reported in Chapter 9 and the comparative assessment of their results is presented in Chapter 10.

CHAPTER 9

Agglomeration Estimates - Approach

9.1 Introduction

This chapter reports the approach and outcome of computing agglomeration dis-benefits associated with a 10% rail capacity constraint using different methods. This is a precursor to a comparative assessment of these approaches presented in Chapter Ten. As explained in the research methodology (Chapter 3), this research estimated the agglomeration economies in urban rail based on the following two measures.

1. The change in the proximity of workers in metropolitan Melbourne to firms in the Central Business District (CBD).
2. The potential CBD employment suppression impact.

The first measure is estimated using the approach that the UK Department for Transport (DfT) (2009) and the New Zealand Transport Agency (NZTA) (2008) adopts to estimate agglomeration benefits. This is referred to as the PETE method in this research as it essentially measures the change in **P**roximity between **E**mployees **T**o **E**mployers.

The second measure is estimated using 3 different approaches namely:

- the transport modelling output (Chapter 5)
- the CBD employer survey (Chapter 6)
- the secondary data analysis (Chapter 7).

Productivity elasticities from secondary research and data analysis are applied on these employment suppression impacts to estimate their associated agglomeration dis-benefits. Figure 9.1 shows how this estimation framework fits into the overall research methodology.

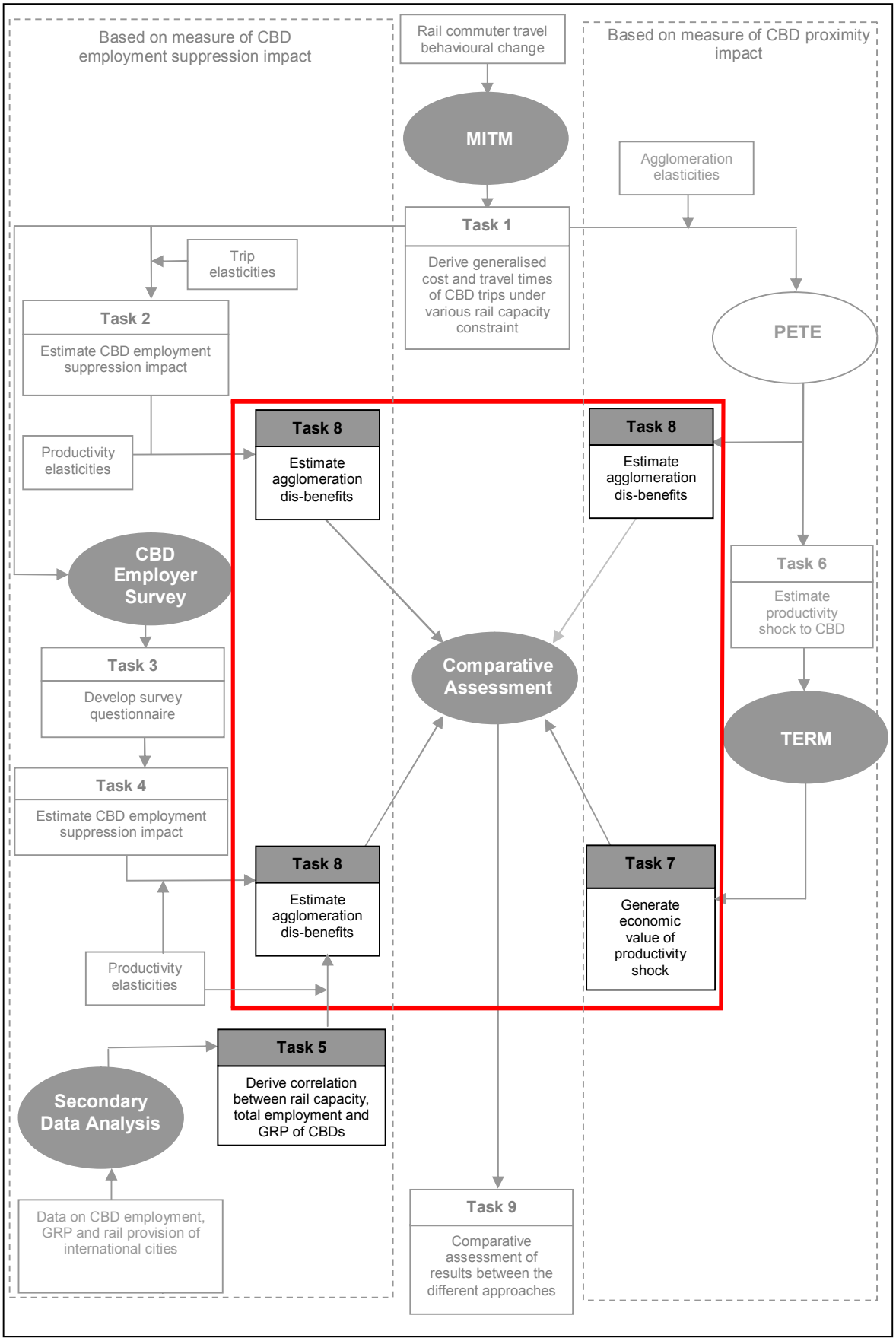


Figure 9.1: Research focus of Chapter Nine

This chapter is structured in the following order.

- **Section 9.2 -** **Estimation based on Proximity Impacts – PETE Method** presents the agglomeration dis-benefits estimated using this method.
- **Section 9.3 -** **Estimation based on Employment Suppression Impacts** reports the agglomeration dis-benefits estimated based on the employment suppression impacts from the 3 approaches mentioned above.
- **Section 9.4 -** **Summary** concludes the chapter.

9.2 Estimation based on Proximity Impacts – PETE Method

9.2.1 Economic Value of Agglomeration Dis-benefits

According to the PETE method, the absolute reduction in a CBD's productivity (dPR_{CBD}) associated with an urban rail constraint can be estimated based on the corresponding productivity loss and the CBD's Gross Regional Product (GRP) as shown in Equation 9.1. The productivity loss to the CBD (δPR_{CBD}) due to the dis-agglomeration effects have been estimated earlier in Section 8.5.1. The results are repeated in Table 9.1 for easy reference.

$$dPR_{CBD} = \delta PR_{CBD}.GRP_{CBD} \qquad \text{(Equation 9.1)}$$

where

- dPR_{CBD} is the absolute drop in the CBD's GRP in dollars
- δPR_{CBD} is the percentage fall in the CBD's productivity (estimated in Section 8.5.1)
- GRP_{CBD} is the GRP of Melbourne CBD.

Table 9.1: Productivity loss associated with a 10% rail capacity constraint for Melbourne CBD (δPR_{CBD})

Sources	Productivity loss
DfT (2009)	-0.09%
NZTA (2008)	-0.08%

To the best knowledge of the author, there is no published information on the GRP of Melbourne CBD or even Melbourne metropolitan area – the non-availability of information for the latter was also highlighted by PricewaterhouseCoopers (PwC) (2009, page 20). It appears that the finest level of a region's output details assembled by the Australian Bureau of Statistics (ABS) is the state level. Therefore, this research used the contribution per worker in Victoria State (Australia) to its Gross State Product (GSP) to proxy the GRP contribution per CBD worker. While this is expected to represent a conservative estimate of the GRP contribution per CBD worker given the knowledge-based economy of the CBD, the approach is broadly consistent with the method used to estimate CBD GRP in the secondary data analysis (Chapter 7).

ABS (2009d) indicated that the GSP for Victoria State in financial year 2005-06 is about $232.8 billion. ABS (2006a) reported that the total employment in Victoria State in 2006 was about 2.4 million. This suggests a contribution of about $97,000 per worker to the GSP of Victoria State. For the purpose of this assessment, it was assumed that a CBD employee also contributes $97,000 per annum to the GRP of Melbourne CBD.

According to the Census of Land Use and Employment (CLUE) (City of Melbourne, 2006), there are about 200,500 workers in Melbourne CBD today (2006). It is estimated in Section 4.2.2 that the total employment for Melbourne CBD will hit 208,500 in the short term and 234,000 in the long term. Based on these employment projections and the GRP contribution of $97,000 per worker, the GRP of Melbourne CBD is estimated to be about $20.23 billion and $22.70 billion in the short and long term respectively. These findings are summarised in Table 9.2.

Table 9.2: Employment and GRP estimates for Melbourne CBD – short and long term

	Short Term	Long Term
Total employment – Melbourne CBD (no. of workers)	208,500	234,000
GRP of Melbourne CBD ($billion) – based on $97,000 GRP contribution per worker	$20.23	$22.70

As reported in Table 9.1, PETE estimates that Melbourne CBD's productivity would fall by -0.08% to -0.09% in both the short and long term due to dis-agglomeration effects from a 10% capacity constraint in urban rail to the CBD. Applying these percentages to Melbourne CBD's GRP figures shown in Table 9.2, it is estimated that the CBD's productivity loss due to dis-agglomeration effects associated with a 10% urban rail constraint is about $16.18 - $18.21 million (average $17.20 million) annually in the short term. Long term estimates are $18.16 million to $20.43 million (average of $19.30 million) per annum. These results are summarised in Table 9.3.

Table 9.3: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short term and long term - estimated using PETE

Source of Agglomeration Elasticy	Economic value ($million – 2006 value) per annum	
	Short Term	Long Term
DfT (2009)	-$18.21	-$20.43
NZTA (2008)	-$16.18	-$18.16
Average	-$17.20	-$19.30

9.2.2 Critique of the PETE Method

Abelson (2009, page 27) commented that the PETE method, which was developed by Graham (2005, 2006a, 2006b, 2007b), is “a highly competent and comprehensive” approach to measure agglomeration economies associated with transport improvement. According to PwC’s (2008, page 19) assessment, the PETE methodology “appears adequately robust for use”. The step-by-step guideline provided by DfT (2009) and NZTA (2008) further enhances the user-friendliness of PETE.

The recent work of Graham and Van Dender (2009), however, suggests that the conventional method to estimate agglomeration benefits “shows a high degree of sensitivity to treatment for unobserved heterogeneity and to differences in the sample of agglomeration”. They suggest that further research is needed.

Abelson (2009) also raised several technical issues pertaining to this approach - for example, Abelson highlighted that the use of turnover (which reflects price) as the measure of output variable in Graham’s model may overestimate the impact in particular for denser areas, where the prices are expected to be higher.

Apart from this, this research also raises the following issues:

1. An accurate assessment of the agglomeration elasticity is fundamentally important to the PETE approach. The differences in the agglomeration elasticities used by DfT (2009) and NZTA (2008) suggest that these values may not be transferable across geographical regions. NZTA (2008) highlighted that the elasticities currently used in their appraisal are interim values adapted from British studies and that they are presently conducting their own empirical research to estimate local elasticity values. This seems to substantiate the possible non-transferability of agglomeration elasticities. Therefore, prior to applying PETE, extensive efforts are required to develop agglomeration elasticity values that reflect local conditions.

2. The estimation of the weighted average generalised cost of travel based on outputs from transport modelling is central to PETE's computation framework. Sensitivity analysis conducted by this research suggests that a slight fluctuation in the transport modelling output would substantially change the eventual agglomeration benefit estimation. PETE may therefore not be suitable to measure the agglomeration benefits associated with minor transport improvements where the change in the generalised cost of travel is within the range of transport modelling accuracy.

3. As will be demonstrated in Chapter 10, PETE may have underestimated the agglomeration benefits associated with transport improvements. This is because the method only measures the direct agglomeration effects and may not capture the inter-regional flow-on effects of the increase in employment agglomeration due to transport improvements.

Pertaining to the first issue, while the use of Melbourne data would likely improve the accuracy of this research, PwC's (2008) assessment suggests that there is no current evidence that the values adapted from British studies are likely to be significantly different to the Melbourne equivalent. Having said so, future studies to collect Melbourne data should be mindful of the issues raised by Graham and Van Dender (2009) and Abelson (2009).

To mitigate the second issue, this research took the generalised cost of travel associated with various levels (i.e. 10% - 50%) of rail capacity constraint to estimate a generalised cost associated with an average 10% rail capacity constraint. These were presented in Table 8.13 and have been used in the estimation of the productivity shocks in the previous chapter. And lastly, this research uses a CGE model (as demonstrated in Chapter 8) to properly capture both the direct and inter-regional flow-on effects of agglomeration associated with transport improvements.

9.3 Estimation based on Employment Suppression Impacts

This section reports the agglomeration dis-benefits estimated based on the employment suppression impact measure. Figure 9.2 shows the assessment framework adopted to estimate such dis-benefits using the employment suppression impacts derived from MITM's outputs, the CBD survey findings as well as secondary data analysis.

As shown in Figure 9.2, the outputs from TERM modelling (Chapter 8) and MITM modelling (Chapter 5) were first used to derive a set of productivity elasticities for Melbourne CBD for both the short and long term. These findings are reported in Section 9.3.1.1. In addition, the average productivity elasticity value (of 0.12) for CBDs derived from the secondary data analysis of international cities (Section 7.5.2.2) was also applied on the employment suppression impacts based on MITM's output to estimate the possible economic value of the associated dis-agglomeration effects. This is presented in Section 9.3.1.2.

The elasticities derived in Section 9.3.1.1 were subsequently applied on the employment suppression impacts derived from the CBD employer survey and the secondary data analysis to estimate the associated agglomeration dis-benefits. These are reported in Section 9.3.2 and 9.3.3 respectively.

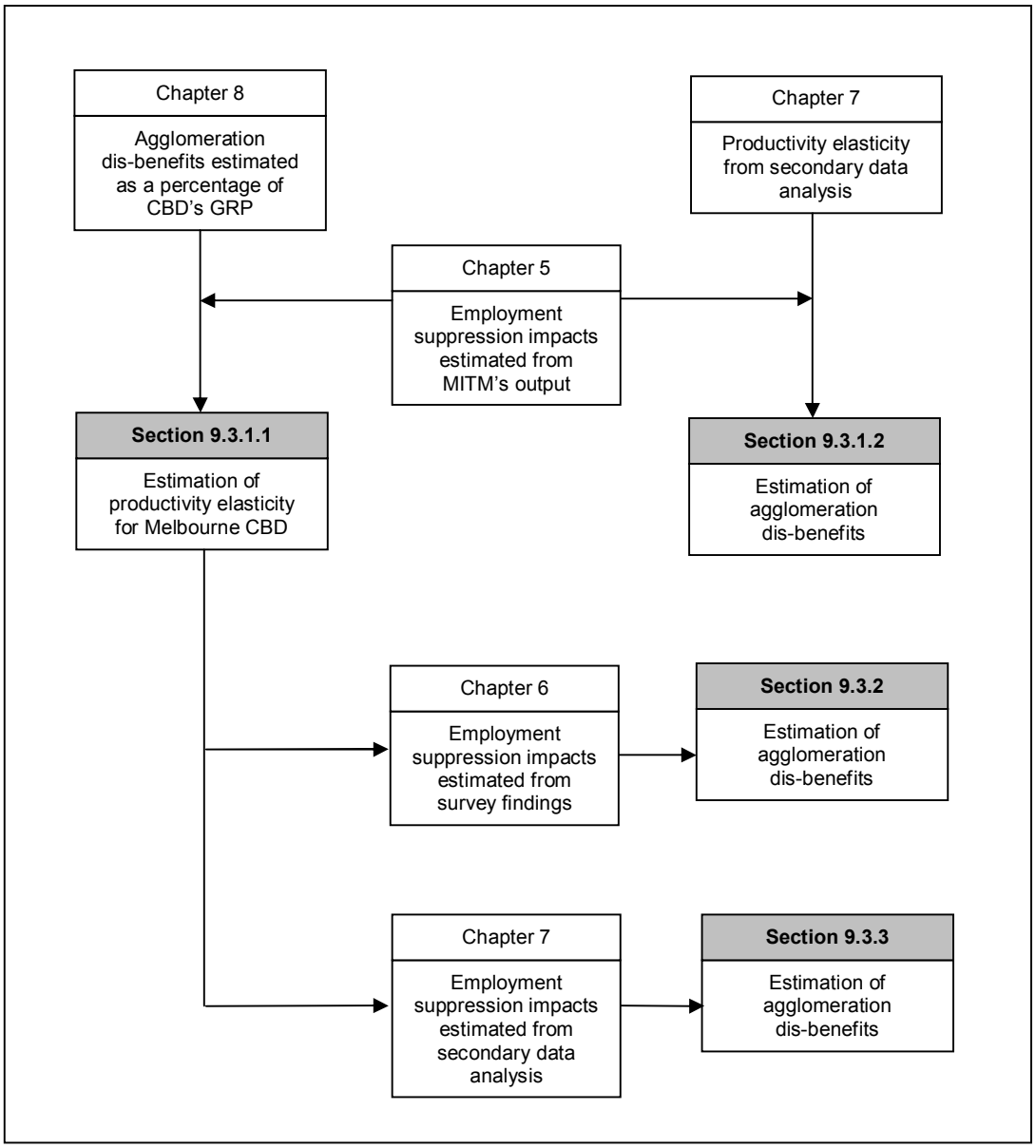


Figure 9.2: Estimation framework for agglomeration dis-benefits based on employment suppression impact measure

This section is organised as follows:

- **Section 9.3.1 - Estimation based on MITM Output**
- **Section 9.3.2 - Estimation based on CBD Employer Survey Findings**
- **Section 9.3.3 - Estimation based on Secondary Data Analysis Findings.**

9.3.1 Estimation based on MITM Output

9.3.1.1 Estimation of Productivity Elasticity for Melbourne CBD

Based on MITM's output and trip elasticities (from secondary research), it was estimated in Chapter 5 that a 10% rail capacity constraint in the AM peak is associated with a 0.69% - 1.07% drop in Melbourne CBD's labour supply in the short-run (SR). TERM modelling (Chapter 8) has estimated that the corresponding productivity deterioration may cost Melbourne CBD -0.09% to -0.10%[1] of its GRP in the SR. Since both the employment suppression and GRP impacts are associated with a 10% rail capacity constraint, it would be reasonable to assume that the two sets of figures are correlated i.e. the -0.09% to -0.10% fall in the CBD's GRP is associated with the employment drop of 0.69% to 1.07%. Adopting this assumption, this research estimated the productivity elasticity values for Melbourne CBD in the short term.

Using these employment suppression impacts and the direct CBD impacts from TERM, it is estimated that Melbourne CBD has a short term productivity elasticity range of 0.08 – 0.15 (average of 0.12). This range of productivity elasticity values means that a 1% reduction in Melbourne CBD's employment is associated with an additional fall of 0.08% to 0.15% in its GRP due to dis-agglomeration effects – i.e. the total fall in the CBD's GRP is 1.08% to 1.15% of which the extra 0.08% to 0.15% is caused by the dis-agglomeration effects. These results are summarised in Table 9.4.

This 0.08 – 0.15 range of productivity elasticities suggest that doubling the employment concentration of the CBD could lead to a short term gain in the CBD's productivity between 6% ($=2^{0.08} - 1$) and 10.8% ($=2^{0.15} - 1$)[2]. This represents an average productivity gain of 8.4%.

[1] The direct CBD effects presented in Figure 8.7 were used in these calculations. This research viewed that since the employment suppression impacts were estimated on the basis of the CBD, it would be more consistent to also use the direct CBD impacts to estimate the corresponding productivity elasticities.

[2] Various studies (e.g. Graham and Van Dender, 2009, Rosenthal and Strange, 2004) have suggested this method of estimation to provide a discrete approximation of the productivity gains due to large changes in the economic mass.

It was also estimated in Section 5.6.4 that a 10% rail capacity constraint is associated with a potential drop of 1.21% - 1.88% in the CBD's labour supply in the long-run (LR). TERM estimated a direct LR impact of -0.25% to -0.29% on the CBD's GRP. Using the same approach mentioned above, a long-run (LR) productivity elasticity range of 0.14 – 0.24 was derived (average of 0.19). The LR results suggest that a doubling of the CBD employment may be associated with a 10.0% ($=2^{0.14} - 1$) to 18.0% ($=2^{0.24} - 1$) (or average of 14.0%) relative productivity gain in the longer term. These results are summarised in Table 9.4.

Table 9.4: Productivity elasticity for Melbourne CBD in short-run (SR) and long-run (LR) – **based on outputs from TERM and MITM**

	CBD employment suppression impact (from MITM)	**GRP loss (from TERM)***	**Resultant productivity elasticity**	**Average productivity elasticity**
SR	0.69% (lower limit)	-0.10%	0.15	0.12
	1.07% (upper limit)	-0.09%	0. 08	
LR	1.21% (lower limit)	-0.29%	0.24	0.19
	1.88% (upper limit)	-0.25%	0.14	

Note: * expressed as percentage of Melbourne CBD's GRP.

Overall, the assessment suggests that the average productivity elasticity for Melbourne CBD for both short and long term is about 0.12 – 0.19. This is higher than the 0.04 – 0.11 productivity elasticity range identified from the literature review (see Section 2.6.4). The average elasticity range of 0.12 – 0.19 estimated for Melbourne CBD is consistent with the findings of Graham (2007a) and Melo et al. (2009) who suggested that regions with a higher concentration of knowledge-based sectors (such as the CBD) are likely to enjoy higher benefits from agglomeration effects. The results suggest that doubling the employment size of Melbourne CBD may increase its productivity by 8.7% ($=2^{0.12} - 1$) to 14.1% ($=2^{0.19} - 1$). This supports the earlier proposition that a doubling of employment size of the CBD may increase its productivity by an additional amount close to or higher than 8%.

The range of productivity elasticities for the short and long term derived here are applied on the employment suppression impacts obtained through the survey and secondary data analysis to estimate the value of their corresponding agglomeration dis-benefits. The results are reported in Sections 9.3.2 and 9.3.3 respectively.

9.3.1.2 Economic Value of Agglomeration Dis-benefits

Secondary data analysis (Section 7.5.3.1) estimated an average productivity elasticity of 0.12 for CBDs. This is the same value as the average SR productivity elasticity estimated for Melbourne CBD – see Table 9.4. However, the LR elasticity value of 0.19 shown in Table 9.4 is higher than the elasticity value of 0.12 estimated from the secondary data analysis. The higher LR elasticity value estimated here is because the direct intra-regional GRP effects were used in the estimation. Should net national effects be used instead, the resultant elasticity value would be closer to 0.12. This suggests that 0.12 could be a more plausible conservative value of the productivity elasticity for Melbourne CBD for both SR and LR. This 0.12 elasticity value is therefore used with the fall in the productivity of Melbourne CBD associated with the SR and LR employment suppression impacts derived from MITM's outputs to estimate their corresponding agglomeration dis-benefits. The results are shown in Table 9.5.

Table 9.5: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short term and long term
– based on MITM's outputs and elasticity of 0.12

	Employment suppression impact	Agglomeration dis-benefits (% of CBD's GRP)	Average %
SR	0.69% (lower limit)	-0.08%	-0.11%
	1.07% (upper limit)	-0.13%	
LR	1.21% (lower limit)	-0.15%	-0.18%
	1.88% (upper limit)	-0.23%	

Table 9.5 suggests that a 10% rail capacity constraint which is associated with a SR labour supply suppression impact of -0.69% to -1.07%, could potentially reduce the CBD's economy by about -0.08% to -0.13% respectively (average of -0.11%). For the LR, the dis-agglomeration effects of the labour supply suppression impact of 1.21% - 1.88% is estimated to lower the CBD's economy potentially by -0.15% to -0.23% respectively (or average of -0.18%). These values are noted to be higher than the estimates from TERM and PETE.

9.3.2 Estimation based on CBD Employer Survey Findings

Section 9.3.1.1 derived a short term productivity elasticity range of 0.08 – 0.15 (average of 0.12) for Melbourne CBD. The CBD Employer Survey (Chapter 6) concluded that a 10% rail capacity constraint may be associated with a SR CBD labour demand suppression impact of -0.97% ± 0.13%. Based on the SR elasticity range of 0.08 – 0.15 derived earlier, it is estimated that the -0.97% drop in employment may lower Melbourne CBD's economy by an additional -0.08% to -0.14% (average of -0.11%)[3] in the next 1-2 years. The estimates are summarised in Table 9.6.

The survey did not explicitly capture the employment suppression impact associated with rising rail congestion for the longer term. However, the relatively high percentage of firms (11%) that indicated a possible relocation out of Melbourne CBD in the longer term suggests that the LR employment suppression impact associated with a 10% rail capacity constraint is likely to be higher than -0.97%. Therefore, the -0.97% labour demand suppression would yield a conservative estimate of the long term employment impact. Using the long term productivity elasticity range of 0.14 – 0.24 derived earlier (Section 9.3.1.1), it is estimated that the labour demand suppression associated with a 10% rail constraint could at least cost about -0.13% to -0.23% of the CBD's GRP (average impact of -0.18%). These estimates are noted to be in the same order of magnitude as those estimated based on MITM's output. The estimates are summarised in Table 9.6 and are used in the subsequent comparative assessment in Chapter 10.

Table 9.6: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short term and long term – **based on survey findings**

	Employment suppression impact	Productivity elasticity used	Agglomeration dis-benefits (% of CBD's GRP)	Average %
SR	-0.97%	0.08 (lower limit)	-0.08%	-0.11%
		0.15 (upper limit)	-0.14%	
LR	-0.97%	0.14 (lower limit)	-0.13%	-0.18%
		0.24 (upper limit)	-0.23%	

[3] Alternatively, the CBD employer survey results suggest that the -0.97% employment suppression impact has a range of ±0.13% at 95% confidence interval. This means that the employment suppression impact essentially ranges from -0.84% to -1.10%. Using this range of employment suppression impact and the average short term productivity elasticity of 0.12 yielded a CBD GRP impact of -0.10% - -0.13% (average of -0.12%). This is within the -0.08% - 0.14% range presented here.

9.3.3 Estimation based on Secondary Data Analysis Findings

Secondary data analysis (Section 7.5.3.2) indicates that a 10% constraint in the AM peak hour rail capacity constraint is potentially associated with a -1.06% fall in the CBD labour demand. The assessment carried out in Chapter 7 suggests that the employment suppression impact estimated via the secondary data analysis may be associated with SR impacts.

Again, the SR productivity elasticity range of 0.08 – 0.15 estimated for Melbourne CBD in Table 9.4 was applied on the -1.06% employment suppression impact found through the secondary data analysis. It is estimated that the -1.06% employment suppression impact may cause Melbourne CBD's GRP to fall by -0.09% to -0.16% in the short term due to a 10% rail capacity constraint.

For the LR estimation, it is also assumed that the -1.06% employment suppression impact estimated via secondary data analysis is a conservative indication of the LR employment suppression impact. Applying the LR productivity elasticity range of 0.14 – 0.24 derived earlier (Section 9.3.1.1), it is estimated that the labour demand suppression associated with a 10% rail constraint could at least cost about -0.14% to -0.25% of the CBD's GRP. These estimates are presented in Table 9.7 and are used in the subsequent comparative assessment for the short term in Chapter 10.

Table 9.7: Agglomeration dis-benefits for Melbourne CBD associated with a 10% rail capacity constraint for short term and long term
- based on secondary data analysis findings

	Employment suppression impact	Productivity elasticity used	Agglomeration dis-benefits (% of CBD's GRP)	Average %
SR	-1.06%	0.08 (lower limit)	-0.09%	-0.12%
		0.15 (upper limit)	-0.16%	
LR	-1.06%	0.14 (lower limit)	-0.14%	-0.20%
		0.24 (upper limit)	-0.25%	

9.4 Summary

The objective of this chapter is to explain the approach and outcome of alternative methods to compute the agglomeration dis-benefits associated with a 10% rail capacity constraint estimated based on the proximity impact measure and the employment suppression measure. This is to set the stage for a comparative assessment of the alternative results from these approaches that will be presented in Chapter Ten.

The proximity impact measure is estimated based on the PETE method which is essentially the approach that DfT (2009) and NZTA (2008) adopt to estimate agglomeration benefits – this is referred to as PETE in this research. PETE estimates that Melbourne CBD's productivity would fall by -0.08% to -0.09% in both the short and long term due to dis-agglomeration effects from a 10% capacity constraint in urban rail to the CBD. Based on these GRP impacts, it is estimated that the CBD's productivity loss due to dis-agglomeration effects associated with a 10% urban rail constraint is about $16.18 - $18.21 million (average $17.20 million) annually in the short-run (SR) and about $18.16 million to $20.43 million (average of $19.30 million) per annum in the long-run (LR).

For the employment suppression measure, the outputs from TERM modelling and MITM modelling were first used to derive a set of productivity elasticities for Melbourne CBD for both the short and long term. The assessment estimated an average productivity elasticity of 0.12 – 0.19 for Melbourne CBD for both short and long term which is higher than the typical range of 0.04 – 0.11 found in previous studies. This is consistent with the findings of Graham (2007a) and Melo et al. (2009) who suggested that regions with a higher concentration of knowledge-based sectors (such as the CBD) are likely to enjoy higher benefits from agglomeration effects.

The elasticities derived from the outputs of TERM and MITM were applied on the employment suppression impacts derived from the CBD employer survey and the secondary data analysis to estimate the associated agglomeration dis-benefits. In addition, the average productivity elasticity value (of 0.12) for CBDs derived from the secondary data analysis of international cities was also applied on the employment suppression impacts based on MITM's output to provide another possible estimate of the dis-agglomeration effects associated with an urban rail constraint. The SR and LR agglomeration dis-benefits estimated from these different approaches (expressed as a percentage of the CBD's GRP) are summarised in Figure 9.3.

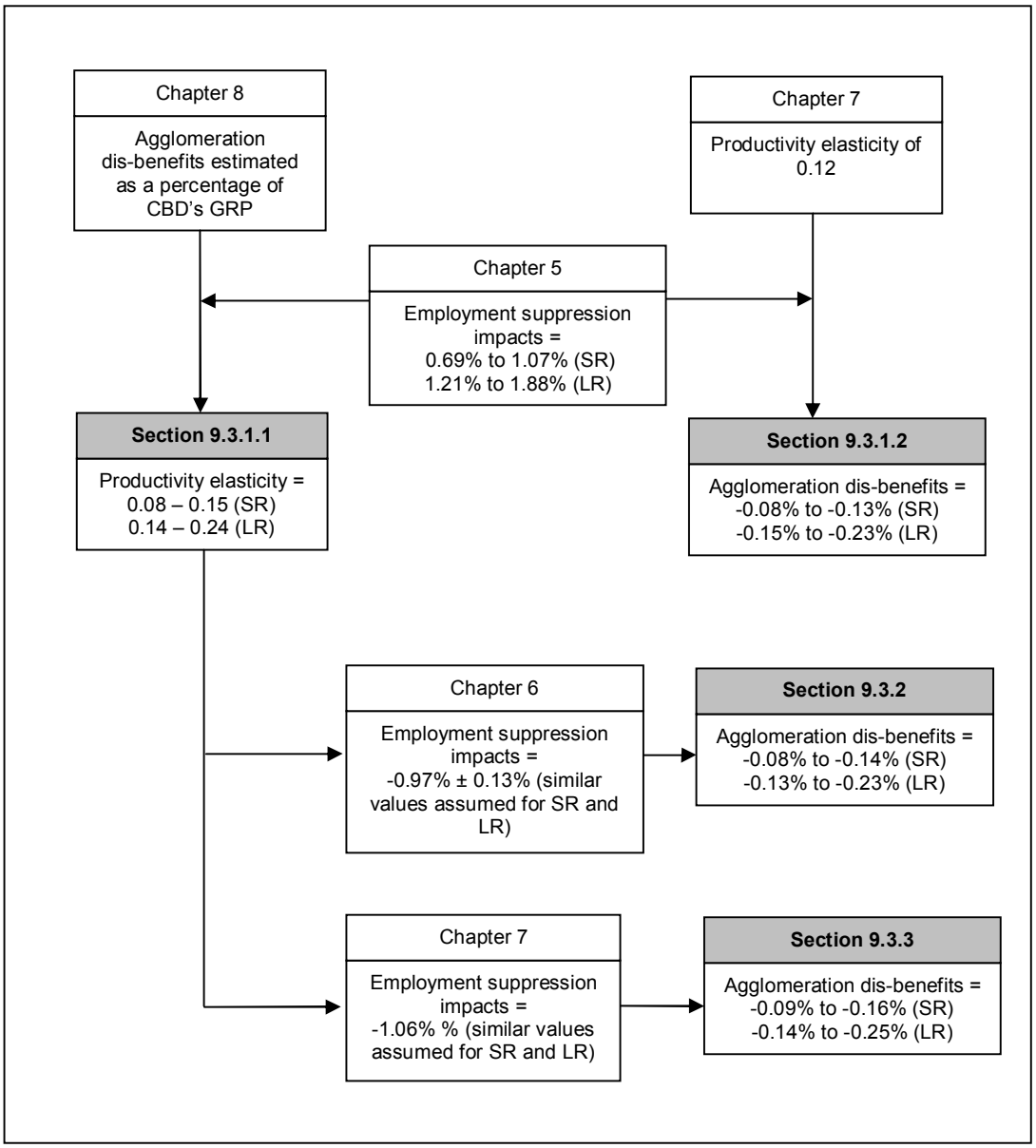


Figure 9.3: Summary of findings based on employment suppression impact measure

Overall, the agglomeration dis-benefits based on the employment suppression measure estimated using different approaches are of the same order of magnitude. This suggests that there is at least some level of robustness in the approach. However, the values estimated based on employment suppression impacts are higher than those estimated by PETE and TERM. A comparative assessment which explores these differences is reported in the next chapter.

CHAPTER 10

Agglomeration Estimates - Comparative Assessment

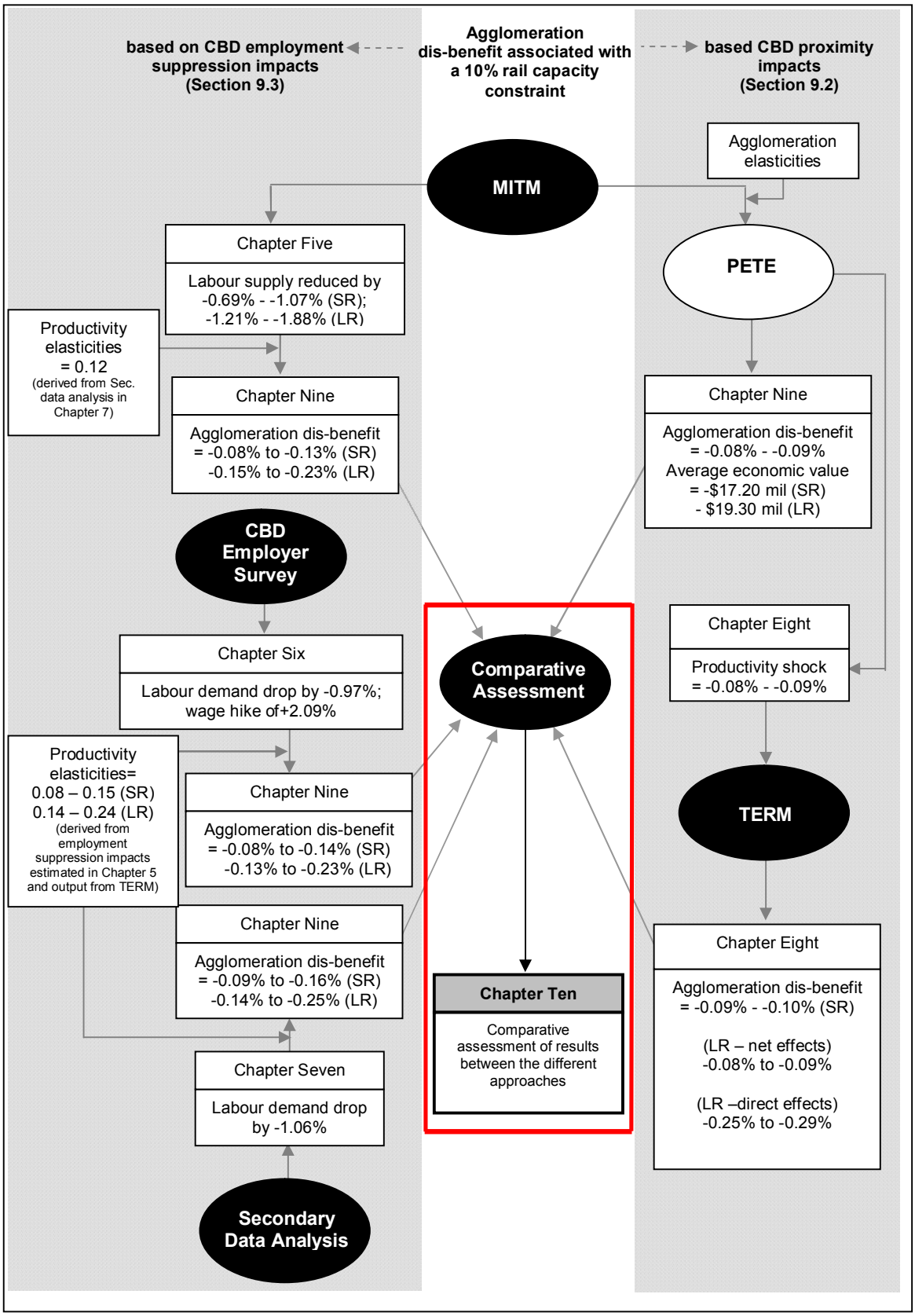
10.1 Introduction

This chapter presents a comparative assessment of the agglomeration dis-benefits estimated via the different approaches in Chapter 9. Such an assessment is useful as it may offer some insight on the merits of the two measures of agglomeration adopted as well as the various estimation approaches used in this research.

Figure 10.1 shows how this comparative assessment (shown boxed in red) fits into the overall framework of this research. To facilitate the flow of this chapter, the key results derived from these two measures of agglomeration as estimated via the various approaches are also summarised in Figure 10.1. The results shown in the left column of Figure 10.1 are estimates based on employment suppression impacts (estimated in Section 9.3). Those based on the change in the CBD's proximity are shown in the right column (estimated in Section 9.2). The results are expressed as a percentage fall in the Gross Regional Product (GRP) of Melbourne CBD.

This chapter is structured in the following order.

- **Section 10.2 -** **Short Term Impacts** present the comparative assessment of the short-run (SR) agglomeration dis-benefit estimates from various approaches.
- **Section 10.3 -** **Long Term Impacts** compare the long-run (LR) outputs from TERM with the long term estimations from the other approaches.
- **Section 10.4 -** **Summary** concludes the chapter.



Note: the agglomeration dis-benefits are expressed as a percentage of Melbourne CBD's Gross Regional Product (GRP)

Figure 10.1: Research focus of Chapter Ten and summary of agglomeration dis-benefit estimates from various approaches

10.2 Short Term Impacts

Figure 10.2 presents the comparative assessment of the agglomeration dis-benefits associated with a 10% rail capacity constraint in the short-run (SR) estimated using different approaches. The results are shown as a percentage fall in Melbourne CBD's GRP. The estimates based on the employment suppression impact measure are represented by the first 3 columns on the left; the two columns on the right represent the results from PETE and TERM.

The result from TERM shown in Figure 10.2 is essentially the output from TERM for the Inner Melbourne region reported in Chapter Eight. As explained in Section 8.3.2.1, it is assumed in the TERM modelling exercise that Melbourne CBD would behave in the same way as Inner Melbourne region. Therefore, the GRP impact of Inner Melbourne region as estimated by TERM is taken to be the impact on Melbourne CBD's GRP in this comparative assessment. Also, as TERM's result suggests that the inter-regional flow-on effects in the short-run are negligible, the result shown in Figure 10.2 can be considered as either the direct or net effects on Melbourne CBD.

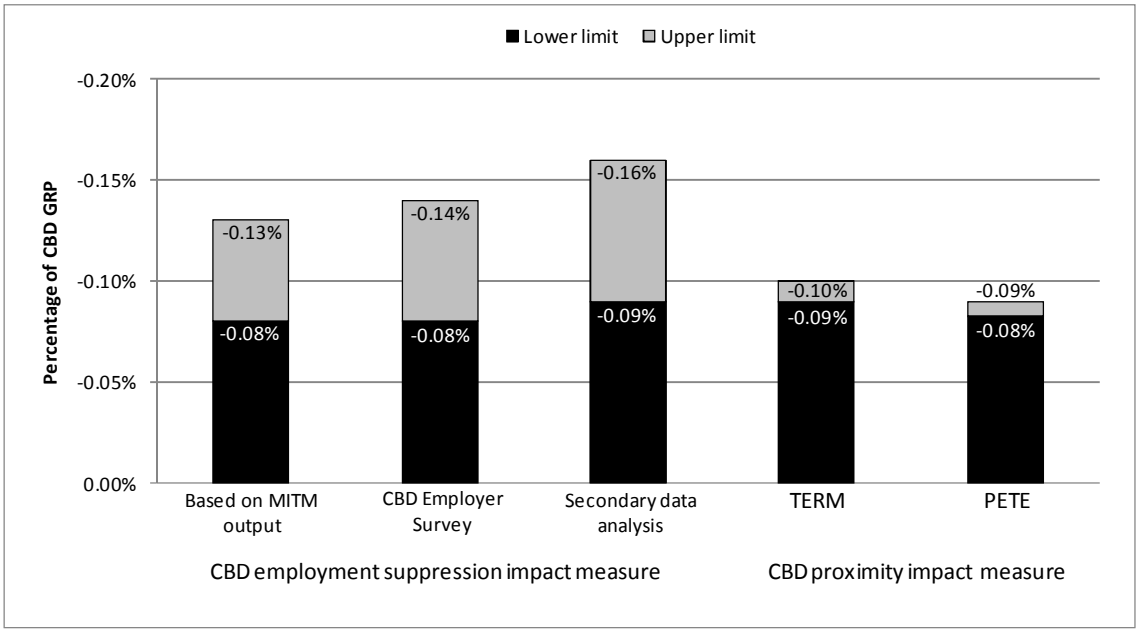


Figure 10.2: Comparative assessment of the potential SR agglomeration dis-benefits (per annum) associated with a 10% rail capacity constraint in AM peak

As shown in Figure 10.2, the productivity dis-benefits based on the employment suppression impact measure using different approaches are of the same order of magnitude. This is not surprising since the SR potential employment suppression impacts derived through the 3 different approaches are also in the same ballpark. The slightly lower estimates based on the outputs from the Melbourne Integrated Transport Model (MITM) is because of the lower productivity elasticity (0.12) used in the computation of the agglomeration dis-benefits compared to the elasticity range (0.08 – 0.15)[1] applied on findings from the survey and secondary data analysis. Nonetheless, the closeness of their dis-benefit estimates suggests that there is some robustness in the employment suppression based measure.

It also appears from Figure 10.2 that the PETE estimates for the short term are about 10% lower than the estimates from the TERM modelling approach. As reported in Chapter 8, TERM's output indicates that the inter-regional flow-on effects to the other regions in the short term are negligible. The difference in the estimates from TERM and PETE may be interpreted simply as the intra-regional flow-on effects within the CBD itself. Section 8.6.2 explained how TERM modelled the productivity deterioration of firms in a region cascading through its economy via the various input-output linkages with the other economic agents within the region (e.g. fall in household income and consumption, reduction in investments among firms and trade deficit). The CGE modelling approach examines each input-output linkage between the economic agents and estimates the resultant economic effects. Such estimation is expected to be more comprehensive than the PETE approach. PETE, which uses agglomeration elasticities estimated based on the turn-over of firms, may not fully capture the impacts on all economic agents in the CBD.

[1] The elasticity value of 0.12 was derived from secondary data analysis (Section 7.5.3.1) while the 0.08 – 0.15 elasticity range was estimated using outputs from MITM and TERM modelling (Section 9.3.1.1). The upper limit elasticity value of 0.15, which is higher than 0.12, accounts for the higher agglomeration dis-benefit estimates based on the employment suppression impacts from the findings of the survey and the secondary data analysis.

Various literature (such as Sveikauskas, 1975, Segal, 1976, Nakamura, 1985, Tabuchi, 1986, Ciccone and Hall, 1996, Rice et al., 2006) have suggested that agglomeration economies are related to increasing returns[2] in production. As explained in Section 8.4.2, this research circumvented the constant returns to scale (CRTS) assumption in TERM partially by changing the underlying condition to increasing return to scale for the primary input factors in Inner Melbourne region via the application of productivity shocks. While this may relegate any concern about TERM being CRTS to a secondary issue, the estimates from TERM might be conservative since the other regions in TERM are still based on CRTS assumption. If this argument is adopted, it also follows that the PETE approach is also likely to have under-estimated the economic value of such dis-agglomeration effects since PETE's estimates are lower than the estimates from the TERM modelling approach. This is an important finding because PETE is presently the common methodology adopted to estimate agglomeration economies.

Figure 10.2 suggests that the upper limits of the productivity dis-benefits estimated based on the employment suppression impact measure are higher in value and wider in range than the estimates from TERM and PETE. On average, the estimates based on employment suppression impacts are about 25% higher than those based on the change in proximity. The former approach yields an average annual dis-benefit range of -0.08% to -0.14% of the CBD's GRP while the average annual GRP impact estimated from TERM and PETE is about -0.09% to -0.10%.

To explain why the estimates based on the employment suppression impact measure are higher than those estimated by TERM and PETE, this assessment examined the following three hypothetical scenarios.

1. The employment suppression impacts are over-estimated.
2. The productivity elasticities applied on the employment suppression impacts are too high for Melbourne CBD.
3. The estimates from TERM and PETE are under-estimated.

[2] According to McTaggart et al. (2007), with given inputs, increasing returns to scale occur if the percentage increase in output is higher than the percentage increase in inputs (i.e. if a firm doubles its inputs, its output will more than double).

Based on the findings of Chapters 5, 6 and 7, it is apparent that the employment suppression impacts estimated from transport modelling, the CBD employer survey and secondary data analysis are in the same order of magnitude. The fact that the three distinctively different approaches arrived at the same ball park estimate of the potential employment suppression impact associated with an urban rail constraint indicates that there is some level of robustness in these results. There is hence no evidence to suggest that the employment suppression impacts estimated using these three distinctively different approaches is over-estimated.

On the 2nd hypothetical scenario, Section 9.3.1.1 has earlier concluded that the average productivity elasticity range (of 0.12-0.19) for Melbourne CBD is consistent with the findings of other studies (such as Graham, 2007a and Melo et al., 2009) which found that regions with a higher concentration of knowledge-based sectors are likely to enjoy higher benefits from agglomeration effects i.e. have higher elasticities. In addition, secondary data analysis based on data from international cities (Chapter 7) estimated an average productivity elasticity of 0.12 for CBDs which is within the range of productivity elasticity estimated for Melbourne CBD. This evidence suggests that the productivity elasticities applied on the employment suppression impacts are reasonable.

If this argument is adopted, it appears that the differences in the agglomeration estimates based on the employment suppression impact measure and those estimated by TERM and PETE are due to the conservative results generated by the latter approaches. The higher estimates derived from the employment suppression impacts may therefore give an indication of the potential estimates from an increasing returns to scale model[3].

In consideration of the above analysis, it may be concluded that a reasonable value of the agglomeration dis-benefit associated with a 10% rail capacity constraint in the short term is likely to lie in between the average estimates from the 2 measures i.e. between -0.08% to -0.14% (from the employment suppression impact measure) and -0.09% to -0.10% (from the proximity impact measure). Taking the average of the estimated agglomeration dis-benefit values from these 2 measures, the average annual agglomeration dis-benefits associated with a 10% rail constraint in the short term is estimated to be about <u>-0.08% to -0.12% of the CBD's GRP).</u>

[3]i.e. a model where increasing returns to scale assumption is adopted for all regions.

10.3 Long Term Impacts

Figure 10.3 presents the comparative assessment of the agglomeration dis-benefits associated with a 10% rail capacity constraint in the long-run (LR). Similar to Figure 10.2, the LR results are also expressed as a percentage fall in the GRP of Melbourne CBD. The first 3 columns on the left are based on the employment suppression impact measure while the 4th – 6th columns represent the results from TERM and PETE.

It is to be noted that the estimates based on the employer survey and secondary data analysis are derived by assuming that the SR employment impacts persist in the long term. On the other hand, as TERM forecasts significant flow-on effects to the other regions for the LR, Figure 10.3 includes both TERM's estimates of direct effects on the CBD alone as well as the net national effects (which consider the inter-regional flow-on effects) for comparison.

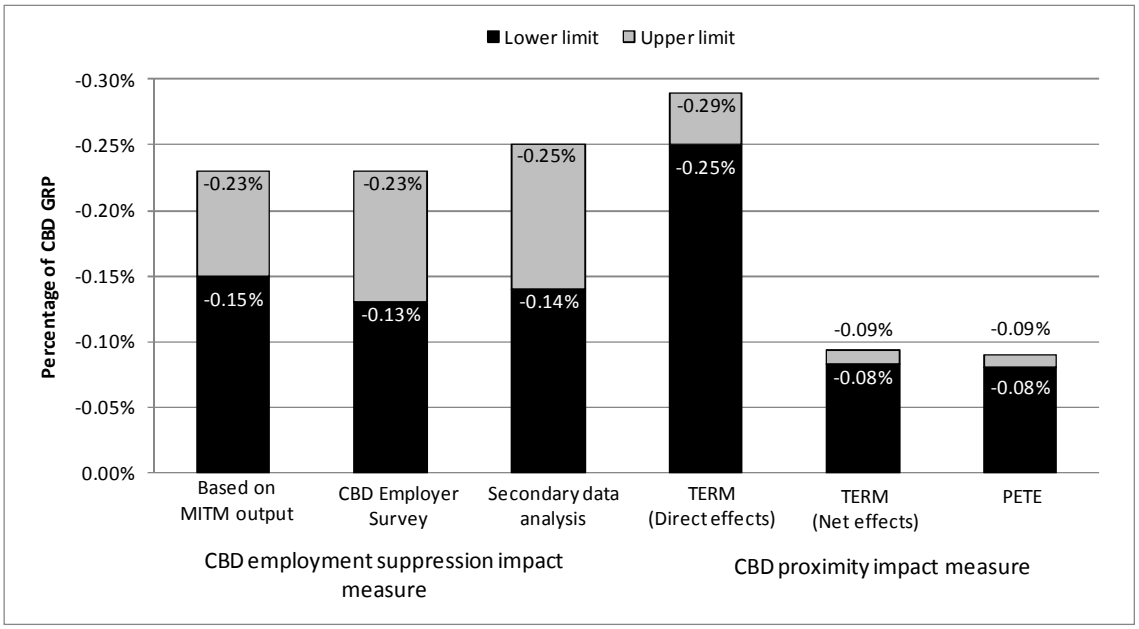


Figure 10.3: Comparative assessment of the potential LR agglomeration dis-benefits (per annum) associated with a 10% rail capacity constraint in AM peak

The LR results show wider discrepancies compared to the SR analysis. This reflects the greater difficulty involved in achieving a reasonable estimate for the longer term and hence more uncertain futures.

Similar to the short term assessment, the LR productivity dis-benefits estimated based on the employment suppression impact measure using different approaches all in the same order of magnitude but higher than the SR dis-benefits – see 1st to 3rd columns from left in Figure 10.3. This supports the earlier proposition that there is some level of robustness in the employment suppression based measure for estimating agglomeration economies in urban rail.

While TERM's output in the short term can be considered as either the direct or net effects on Melbourne CBD, since the inter-regional flow-on effects are insignificant, this is not the case for the long term. As reported in Chapter Eight, TERM's results indicate that the LR inter-regional flow-on effects are substantial and they help to negate the direct detrimental effects of the CBD's productivity deterioration. The direct impact on Melbourne CBD is represented by the 4th column in Figure 10.3 while the 5th column represents TERM's estimates of the net national effects (i.e. with the inter-regional flow-on effects considered). As reported in Chapter 8, the inclusion of the inter-regional flow-on effects essentially bring the long term net effects to -0.08% to -0.09%; this is almost the same level as the SR results.

As observed from Figure 10.3, the direct GRP impact on Melbourne CBD in the LR estimated by TERM is close to the upper limit estimates based on the employment suppression impact measure – i.e. the 1st to 3rd columns. On the other hand, the net flow effects of a productivity deterioration in Melbourne CBD forecasted by TERM (5th column) is of similar value to that derived using PETE (6th column). This suggests that the significant inter-regional flow-on effects may explain the wide disparities between the estimates based on the employment suppression impact measure and that based on the CBD proximity change measure.

Given the wide discrepancies in the agglomeration dis-benefit estimates with and without considering the potential inter-regional flow-on effects, it may be meaningful to examine the direct CBD impacts and the overall net effects separately. Figure 10.4 presents a comparative assessment of the direct effects while Figure 10.5 compares the net effects.

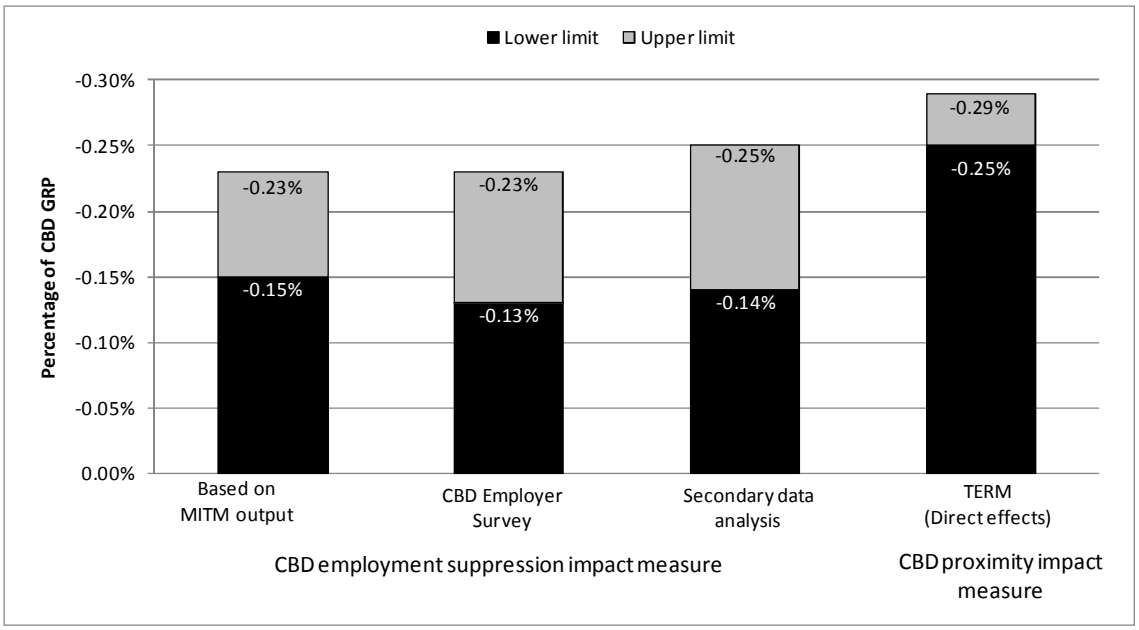


Figure 10.4: Comparative assessment of the potential LR agglomeration dis-benefits (direct effects) on Melbourne CBD

As highlighted earlier, the direct GRP impact on Melbourne CBD in the LR estimated by TERM is in the same order of magnitude as the upper limit estimates based on the employment suppression impact measures. This is presented in Figure 10.4. This suggests that the employment suppression impact measure may have only captured the direct impact on Melbourne CBD and did not consider the secondary employment effects to the other regions. Nonetheless, the fact that these estimates are in the same ballpark suggests that the direct productivity deterioration impact on Melbourne CBD in the LR is reasonably robust and may cost, on average, 0.16% - 0.25% of the CBD's GRP. This is about twice the short term effect.

The result suggests that a major drawback of the employment suppression impact measure of agglomeration effects is its lack of capacity to consider the secondary employment effects to the other regions in the longer term. This is not a concern for SR estimation since the inter-regional employment movements are not expected to be significant, as shown by TERM's outputs. This inadequacy of the employment suppression impact measure clearly highlights the value of the TERM approach in showing the LR effects on other regions. This is an important contribution of this research.

The importance of this finding is two fold. Firstly, it contributes to the understanding of the overall effect of agglomeration economies in urban rail, in particular the associated inter-regional effects. This is beneficial in the appraisal of future rail proposals. TERM's results show that the dis-agglomeration effects associated with an urban rail constraint may go beyond the travel corridor or area examined which is the usual scope of current assessment. Secondly, this finding helps to address the double-counting ambiguity pertaining to agglomeration benefits (as mentioned in Section 2.5.2.1) by showing exactly the regions that will benefit and lose from the transport improvement.

In consideration of the significance of the inter-regional flow-on effects, and recognising that economic benefits associated with a transit system may lag many years after implementation, a CGE modelling approach may therefore represent a more comprehensive platform to examine agglomeration effects in urban rail, in particular, if an increasing returns to scale approach is used. This is an area for future refinement.

Based on TERM's output, it is estimated that the LR inter-regional flow-on effects are about 65% of the direct economic impacts on the CBD. Assuming that the inter-regional flow-on employment effects are also 65% of the direct CBD employment suppression impacts, the LR annual agglomeration dis-benefits (in terms of percentage impact to CBD's GRP) estimated based on the employment suppression impact measure using various approaches are likely to be as follows (see Figure 10.5):

- Based on MITM's outputs = -0.05% to -0.08%
- Based on the CBD employer survey = -0.05% to -0.08%
- Based on secondary data analysis = -0.05% to -0.09%.

Overall, the comparative assessment indicates that if inter-regional flow-on effects are considered, a reasonable estimation of the overall annual agglomeration dis-benefits associated with a 10% rail constraint in the long term is about -0.06% to -0.09%[4] of the CBD's GRP.

[4] Estimates from TERM and PETE are included in the derivation of this average range.

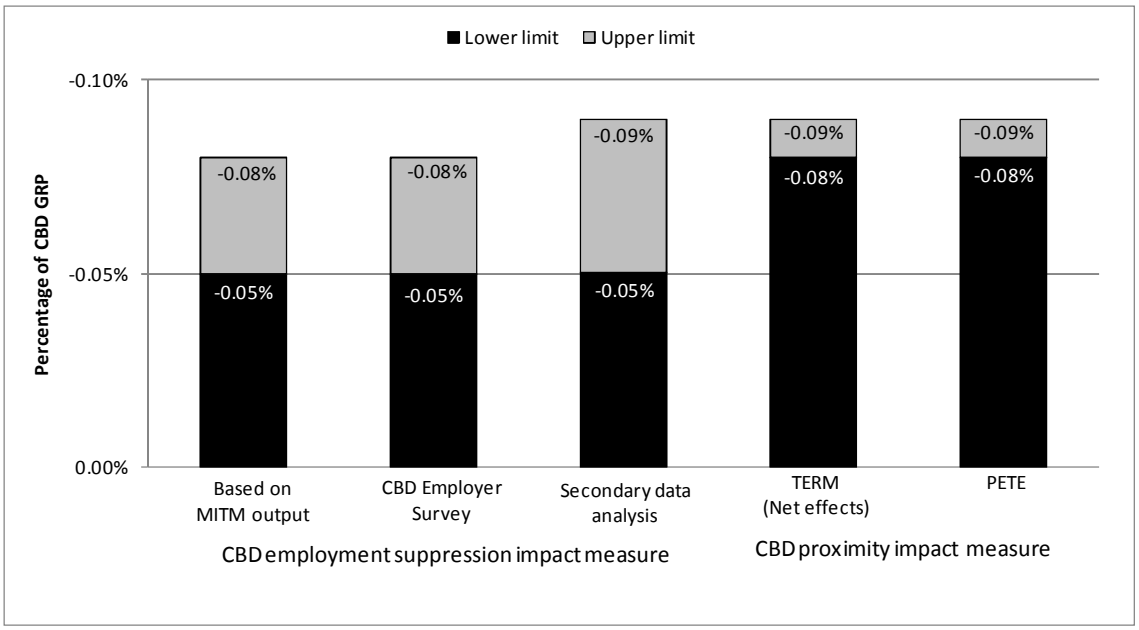


Figure 10.5: Comparative assessment of the potential LR agglomeration dis-benefits (net effects) on Melbourne CBD

Comparison of the results from TERM and PETE indicate that PETE's estimate is about 5% lower than TERM's output (the difference is about 0.004% of the CBD's GRP). While the difference is not large (and is less than the short-term results), it substantiates the earlier proposition that the PETE method is under-estimating the economic value of agglomeration effects in urban rail.

10.4 Summary

This chapter compares the agglomeration dis-benefit estimates associated with a 10% rail capacity constraint estimated using various approaches. Such an assessment is useful because it may offer some insight on the merits of each approach to measuring agglomeration effects.

TERM's output suggests that the flow-on effects to other regions in the short term are negligible. Therefore, the SR estimates from the various approaches are essentially the direct impacts on the CBD's economy. The agglomeration dis-benefits estimated based on the employment suppression impact measure using three different approaches are all in the same order of magnitude. This suggests that there is some robustness in the employment suppression based measure for estimating agglomeration economies in urban rail for the short term.

The comparative assessment of the short term results suggest that the agglomeration dis-benefits estimated using the employment suppression impacts are generally higher in value and wider in range than the estimates from TERM. This is thought to be primarily due to the CRTS assumption underlying TERM. A range of literature has suggested that agglomeration economies are related to increasing returns in production. While this research circumvented the CRTS assumption in TERM partially via the application of productivity shocks on the primary factors in the Inner Melbourne region, the estimates from TERM might still be conservative since the other regions in TERM are still based on CRTS assumption.

The SR assessment also shows that the PETE estimates are generally about 10% lower than the estimates from the TERM modelling approach. This suggests that the PETE method has under-estimated the economic value of agglomeration economies in urban rail since TERM's outputs are conservative. This is an important finding because PETE is presently the common methodology adopted to estimate agglomeration economies.

Overall, the SR results based on both measures of agglomeration suggest that the average annual agglomeration dis-benefits associated with a 10% rail constraint is about -0.08% to -0.12% of the CBD's GRP.

The LR results show wider discrepancies compared to the short-run analysis. This reflects the greater difficulty involved in achieving a reasonable estimate for the longer term and hence more uncertain futures.

Similar to the short term assessment, the productivity dis-benefits in the LR estimated based on the employment suppression impact measure using different approaches are higher than the SR dis-benefits and are all in the same ball park. This supports the earlier proposition that there is some robustness in the employment suppression based measure for estimating agglomeration economies in urban rail.

Comparison of the LR results across the two measures of agglomeration shows that the direct GRP impact on Melbourne CBD in the long term estimated by TERM is in the same order of magnitude as the upper limit estimates based on the employment suppression impact measure. On average, the direct impact is about 0.16% - 0.25% of the CBD's GRP. This is about twice the short term effect. However, TERM's results indicate that flow-on effects to other regions in the longer term are substantial and their inclusion would bring the overall LR net national effect (i.e. -0.06% to -0.09% of the CBD's GRP) to almost the same level as the short term results.

The trend of the flow-on effects as illustrated in TERM's output suggests that the employment suppression impact measure could have over estimated the agglomeration dis-benefits associated with a 10% rail capacity constraint, as the secondary employment effects on other regions have not been considered. This is a drawback of this measure for long term assessment. In addition, this also clearly highlights the value of the TERM approach in showing the LR effects on other regions, which is a key contribution of this research.

In consideration of the significance of the flow-on effects and that economic benefits associated with a transit system may lag many years after implementation, the LR results suggest that a CGE modelling approach may offer the most comprehensive platform to examine agglomeration effects in urban rail.

CHAPTER 11
Conclusions

11.1 Introduction

This chapter concludes the thesis. It presents an overview of the research framework adopted in this study as well as the key findings and contributions of this research. Suggestions for future research are also included at the end of this chapter.

This chapter is structured in the following order.

- **Section 11.2 -** **Overview of Research Framework** summarises the research approach adopted in this study.
- **Section 11.3 -** **Key Results** highlights the main findings of this research.
- **Section 11.4 -** **Research Contributions** presents the major contribution of this research to knowledge.
- **Section 11.5 -** **Assessment of Research Approach** identifies potential areas of improvement for the methodology adopted in this research.
- **Section 11.6 -** **Suggestions for Future Work** proposes possible directions for future research.

11.2 Overview of Research Framework

In recent years, the potential to produce economic benefits has become increasingly important to the decision-making process for urban passenger rail projects. Such benefits are seen as a motivation for rail investment, either by encouraging jobs to locate in a particular location or by opening up new journey-to-work opportunities for residential areas. However, while a significant portion of the benefits are already well captured under the present Cost-Benefit Analysis (CBA) methodology, the current conventional appraisal framework does not take into consideration other potentially significant impacts such as agglomeration benefits.

Agglomeration benefits in production are positive impacts on productivity amongst firms due to an increasing concentration of firms or increasing density of employment or widening of labour markets. A review of past studies indicates that this is a new field where no significant research had been carried out until the recent works of Graham (2005, 2006a, 2006b). A survey of international CBA practices (for urban rail projects) also showed that few countries have incorporated agglomeration benefits (to some extent) in their current CBA framework.

A synthesis of evidence from previous studies suggests that agglomeration effects associated with urban rail projects might be significant. However, the wide range of estimated elasticity values clearly indicates that there is a knowledge gap pertaining to the plausible range of its economic value and the methodology to estimate such effects associated with urban rail.

The focus of this research is to explore the economic impacts of agglomeration economies for urban rail projects. To achieve this objective, a methodology comprising the following five key components has been developed.

1. A secondary research and data analyses framework to gather evidence to support the other components of the research methodology and benchmark their findings.
2. A transport modelling approach using the Melbourne Multi-modal Integrated Transport Model (MITM) from Department of Transport (DOT), Victoria to understand how the AM peak travel time and generalised cost of automobile trips into Melbourne CBD would change under various levels of urban rail capacity constraint i.e. rail demand exceeds rail capacity provision.
3. A web-based survey to gather feedback from Melbourne CBD employers to understand how they perceive rising rail congestion would affect their businesses in the CBD.
4. A Computable General Equilibrium (CGE) experimental modelling approach using the TERM model[1] from the Centre of Policy Studies (CoPs), Monash University to estimate the economic value of the agglomeration effects associated with urban rail projects.
5. A comparative assessment of the agglomeration estimates from various approaches.

[1] TERM stands for The Enormous Regional Model. This is the name given by its creator in the Centre of Policy Studies, Monash University (Horridge et al., 2005).

Given its high development intensity and heavy reliance on the urban rail system for its accessibility, the Central Business District (CBD) of Melbourne is selected as the case study in this research to explore and estimate such agglomeration effects associated with urban rail.

The basic assumption underpinning the research methodology is that the urban passenger rail system serving Melbourne CBD is an enabler of the CBD's economic growth. Therefore, if the urban rail capacity serving the CBD is constrained (i.e. rail demand exceeds rail capacity provision), agglomeration diseconomies due to the corresponding increase in traffic congestion would set in. The poorer accessibility of the CBD may cause some CBD employers to relocate and some CBD employees to suppress their work trips. This is likely to reduce the employment concentration of Melbourne CBD. According to the theory of agglomeration, this drop in the employment concentration is envisaged to cause an overall reduction in the CBD's productivity. It is expected that the economic value of this urban dis-agglomeration will provide a mirror indication of the agglomeration benefits associated with new urban passenger rail provision to ease a capacity constraint. A major motivation for this approach is the overcrowding of Melbourne CBD rail services which has occurred over the last 5 years.

Two measures of agglomeration economies in urban rail are explored in this research - the potential CBD employment suppression impact and the reduction in the proximity between CBD firms and workers arising from an urban rail capacity constraint. The potential CBD employment suppression impacts are estimated using three different approaches - outputs from the MITM modelling and trip elasticity, a CBD employer survey as well as secondary data analysis. These impacts are then used with productivity elasticities (from secondary research and analysis) to estimate the agglomeration dis-benefits associated with an urban rail constraint.

On the other hand, the deterioration in the CBD's accessibility (estimated from MITM's output) has been employed to estimate the agglomeration dis-benefits and to derive a range of productivity shocks, using the method adopted by the UK Department for Transport (2009) and the New Zealand Transport Agency (2008) for estimating agglomeration economies in transport investments[2]. The productivity shocks are then inputted into the TERM CGE model to estimate its impact on Melbourne CBD's Gross Regional Product (GRP).

[2] This method is referred to as the PETE method in this thesis.

11.3 Key Results

The key findings from this research are as follows:

1. Measure of CBD Employment Suppression Impacts

The 3 approaches adopted in this research to measure such impacts consistently found that a 10% rail capacity constraint in the AM peak is associated with an average 0.69% - 1.07% employment suppression impact on Melbourne CBD in the short-term. The potential CBD employment suppression impact is estimated to escalate to 1.21% - 1.88% in the longer term. Overall, the closeness in the estimates of the 3 approaches suggests some level of robustness in this measure of agglomeration effects.

2. Measure of CBD Proximity Impacts

The value of the CGE modelling work lies in the ability of TERM to demonstrate how the initial productivity shock on Melbourne CBD may affect other regions in the short and long term. The TERM modelling output suggests that a 10% rail capacity constraint in the AM peak is associated with direct agglomeration dis-benefits valued at -0.09% to -0.10% of Melbourne CBD's GRP in the short term. The inter-regional flow-on effects to other regions in the short term are negligible. In the long term, the direct effects are found to be twice the magnitude of the short term – about -0.25% to -0.29% of the CBD's GRP. However, unlike the short-run where the flow-on effects are negligible, the long-run inter-regional flow-on effects are significant at +0.17% to +0.19% of the CBD's GRP. The significant and positive flow-on effects in the long-run brings the overall net national agglomeration dis-benefits (i.e. -0.06% to -0.09%) to almost the same level as the short term estimations.

TERM's results are consistently higher than PETE's estimates by about 10% in the short-run and 5% in the long run. This suggests that the PETE method may have under-estimated the economic value of such dis-agglomeration effects. This is an important finding because PETE is presently the common methodology adopted to estimate agglomeration economies.

3. Comparative Assessment

The assessment of the short-run results shows that the agglomeration dis-benefits estimated using the employment suppression impacts are generally higher than the estimates from TERM and PETE. Various literature have suggested that agglomeration economies are related to increasing returns in production. This suggests that the estimates from the employment suppression impact measure could be indicative of the possible estimates from an increasing returns to scale model rather than the constants return to scale as assumed in TERM. Overall, the estimates from the 2 measures of agglomeration economies adopted in this study suggest that the annual agglomeration dis-benefits associated with a 10% rail constraint in the short term is estimated to be about -0.08% to -0.12% of the CBD's GRP.

The long run results show wider variations compared to the short-run analysis. This reflects the higher level of difficulty in achieving a reasonable estimate for the long term given higher uncertainty. The comparative assessment suggests that the wide discrepancies in the estimates between the 2 measures of agglomeration is likely caused by the significant inter-regional flow-on effects to the other regions in the long-run, as shown in TERM's output. This suggests that a major drawback of the employment suppression impact measure of agglomeration effects is its lack of capacity to consider the secondary employment effects to the other regions in the longer term. Overall, the comparative assessment indicates that if inter-regional flow-on effects are considered, a reasonable estimation of the overall annual agglomeration dis-benefits associated with a 10% rail constraint is about -0.06% to -0.09% of the CBD's GRP, which is similar to the short term effects.

11.4 Research Contributions

The following are considered the major contributions of the research to knowledge.

1. The Use of Alternative Methods to Estimate Agglomeration Economies

In general, agglomeration benefits are not considered in the conventional appraisal of transport projects in most countries worldwide. Clearly, there is a range of views about their validity. The only published method currently used to estimate agglomeration benefits in transport investments is the PETE method described in Sections 8.5 and 9.2 based on approaches in the UK and New Zealand. The literature review presented in Chapter 2 of this thesis has concluded that there is room to improve the methodologies to estimate such agglomeration effects. Therefore, there is clearly value in exploring alternative methods of estimating agglomeration effects in transport application as a means to test the robustness and variability of alternative approaches.

This research provides an important contribution to knowledge by exploring a range of alternative methods to estimate agglomeration economies and compares the results of these with the conventional method to understand robustness and variability of outcomes. To the best knowledge of the author, no other published research has undertaken a comparative assessment of this kind.

2. Estimating Agglomeration Economies Using Travel Demand Elasticities

A new approach to estimating agglomeration economies using travel demand elasticities is presented in Chapter 5. In essence, the method relies on trip suppression implied by conventional travel demand elasticities and applies these to work trips to estimate potential changes in employment behaviour associated with an urban rail capacity constraint. Although this approach may be considered crude, it nonetheless represents an alternative means of exploring impacts on employment concentration (i.e. the number of workers per unit area) of a transport project. To the best knowledge of the author, no other published research has adopted the conventional elasticity method in this way.

3. Estimating Agglomeration Economies Using Primary Data Collection

Agglomeration economies are conventionally estimated based on Production Function (PF) using regression models derived from an analysis of firm performance data – see Sections 2.5.1.3 and 2.6. To the best knowledge of the author, agglomeration economies have not been previously derived from primary surveys asking employers how they might react to traffic congestion. Chapter 6 of this research presents a new approach which bases changes in employment on employer stated and expected intentions as they respond to scenarios of future transport congestion. While this approach has a range of methodological weaknesses, it nonetheless represents a new approach to exploring how employment and employment concentration might change as a result of changes in transport and travel.

In addition, the CBD employer survey also reveals how agglomeration economies associated with an urban rail constraint may affect the various sectors and occupations (i.e. professional and non-professional employees) differently. This understanding is of value as it contributes to the understanding of agglomeration effects in disaggregated employment groups and to some possible distributional consequences of major transport initiatives affecting a CBD.

4. Estimating Agglomeration Economies Using Aggregate City Wide Secondary Data Analysis

Chapter 7 presents a new approach to estimating agglomeration economies based on a review of available employment and travel information from aggregate international city data. This research acknowledges that this approach has some methodological concerns regarding data quality - see Section 7.6. Having said so, this method still represents a new approach to exploring agglomeration economies and the findings are consistent with other approaches reviewed.

5. Estimating Agglomeration Economies Using CGE Modelling

Chapter 8 presents a new methodology for estimating agglomeration economies using a CGE modelling platform. The major contribution of the TERM modelling work lies in the ability of TERM to demonstrate how the initial productivity shock on Melbourne CBD may impact other regions in the short and long term.

As TERM contains no modelling of agglomeration economies and there is no published work to date on how to model such effects associated with urban rail in CGE models, the modelling approach developed by this research contributes to the field of CGE modelling in particular for future simulation of agglomeration economies in transport applications. While the modelling approach presented is experimental, it nonetheless represents a new methodology and approach to the field. No previous published research has explored agglomeration economies in CGE models in this manner.

The findings from TERM is important as it suggests that the dis-agglomeration effects associated with an urban rail constraint may go beyond the travel corridor or area examined, which is the usual scope of current assessment. This contributes to the understanding of the overall effect of agglomeration economies in urban rail in particular the associated inter-regional effects, which is beneficial in the appraisal of future rail proposals. It was mentioned in Section 2.5.2.1 that critiques of agglomeration benefits commonly consider agglomeration effects are double-counting travel time savings. TERM's output is therefore also valuable as it can help eradicate the double-counting ambiguity by showing exactly the regions that will benefit or lose from the transport improvement.

6. Agglomeration Diseconomies

The focus of the research case study has been examining agglomeration diseconomies resulting from rail congestion. An important assumption used in this work is that agglomeration diseconomies mirror agglomeration economies when transport capacity is constrained rather than expanded. There is surprisingly little evidence in previous research to make this important assumption. This is because no previous research in the transport field has considered diseconomies related to agglomeration effects. While the assumption may be debatable, the exploration of this issue in this research is new and hence represents a new contribution to knowledge.

To test how well agglomeration dis-benefits mirror agglomeration benefits, this research carried out a benchmarking exercise to quantify the estimated agglomeration dis-benefits associated with a 10% rail capacity constraint as a share of total direct benefits associated with a 10% urban rail provision. The benchmarking assessment suggests that the magnitude of agglomeration dis-benefits in urban rail is potentially within the 25% - 50% 'ball park' estimated by past studies - Marshall and Webber (2007) estimated that agglomeration effects in transport projects could add up to 25% of the total economic benefits; Eddington (2006b, page 14) highlighted that the agglomeration effects could increase the overall project benefits of transport projects 'by up to 50 per cent in some cases'. This may suggest that agglomeration dis-benefits offer a reasonable mirror of agglomeration benefits and that the approaches explored in this research are robust.

7. Links between Rail and Agglomeration Economies

The focus of the research has been agglomeration economies associated with CBD access by rail. A contribution of the research has been to elaborate the important impact which rail access in particular can have on employment concentration. Previous research in the field has generally examined how a range of transport modes can generate agglomeration economies. It is suggested by this research's findings that CBD rail access in particular might be of greater significance than other modes in relation to agglomeration economies given the high employment concentration and knowledge-based economy in CBD's.

11.5 Assessment of Research Approach

This section assesses the limitations of the study approach adopted in this research. These limitations are due to time and resource constraints. The aim of this assessment is to clearly identify these limitations so that they could be addressed in future research.

1. Primary Data Collection

The primary survey of CBD employers achieved a sample size of about 0.6% of CBD employees. This is smaller than the desired 1% of CBD employees as suggested by Neuman (1991). While the participation rate across the various industries, as well as the findings of the firm size analysis carried out in Section 6.3.4.1, suggest that the achieved sample size is acceptable, a larger sample would have been more desirable to improve the robustness of its findings.

In addition, the primary survey was based on employer stated and expected intentions as they respond to scenarios of future transport congestion. There is no way to ascertain whether they will actually carry out their intentions as stated in their survey responses subsequently.

2. Secondary Data Analysis

Several studies (such as Karathodorou et al., 2010 and Coevering and Schwanen, 2006) have highlighted that the omission of other variables known to affect mobility and commuting patterns (such as socio-economic data) and the inconsistencies in the data collection procedures and definitions of the variables are key areas of concerns with regards to the Millennium Cities Database. Even UITP conceded that the database is “obviously not perfect” (Vivier, 2001, page 5). This research presented a critique of the secondary data in Section 7.6.

As reported in Section 7.5.1.1, a sample size of 20 cities is adopted for this assessment. While this meets the minimum requirement, the sample size is far from the optimum size of 45 to 60 (based on the preferred ratio of 15 or 20 observations to 1 independent variable as indicated in Hair et al., (2006, page 197)). This means that the statistical reliability of the result requires careful examination in its application.

3. Travel Elasticities

Conventional travel elasticities were applied to work trips to estimate potential changes in employment associated with an urban rail capacity constraint. There is a methodological concern with this application as travel elasticities are not collected to examine employment change. Further research is clearly warranted to clarify these behaviours.

The long-run employment suppression impact was estimated in Chapter 5 by assuming that the long term impact is twice the short term effect as per travel elasticities. The relatively wider variations in the subsequent long term agglomeration dis-benefit estimations (compared to the short term) clearly suggests that long term elasticities have lesser certainty as it is very difficult to measure travel effects of specific changes over a long period of time.

There may also be some methodological concerns over the adoption of HLB's (2003) findings to formulate the transport modelling assumptions and to estimate the potential employment suppression impact for this research. HLB's (2003) work is very specific and their findings may not be totally or directly transferable to Melbourne. In addition, the use of a single source in the modelling assumption and employment suppression impact estimation places much reliance on the robustness of this source.

4. TERM modelling

As highlighted in Chapter 8, the CGE modelling work carried out in this research is experimental in nature. There is therefore merit to further examine the reasonableness of the productivity shock modelling approach developed by this research.

The TERM model used in this research incorporates Melbourne CBD into the Inner Melbourne region. This is a coarse spatial representation of the CBD which has an industrial structure that is not identical to the Inner Melbourne region. To properly examine the agglomeration impacts of an urban rail constraint on the CBD, it would be desirable to create an individual layer in TERM for Melbourne CBD.

In addition, the CGE modelling approach adopted in this research requires changes in rail commuter travel and the associated productivity shocks to be estimated outside TERM. It would be ideal if the commuter travel behavioural change could be properly represented in TERM as this would allow the TERM model to endogenise the decision making process of commuters (on whether to give up their work trip and subsequently employment). This would better simulate the actual situation in the real-world.

5. Focus on Agglomeration Diseconomies

This research focus on agglomeration economies associated with CBD access by rail. An important assumption used in this work is that agglomeration diseconomies mirror agglomeration economies when transport capacity is constrained rather than expanded. While this assumption seems intuitively correct, there is no backing found in earlier research to support its application.

11.6 Suggestions for Future Research

There is room to improve the presented research methodology. This section proposes several aspects of work for future research in this field.

The agglomeration elasticities adopted in this research are based on the values from DfT (2009) and NZTA (2008). The accuracy of the findings could be improved if local agglomeration elasticity values were available. The extensive data collection and complex regression modelling work involved in deriving local agglomeration elasticity values for Melbourne could be a possible area for future research. These analyses are important in developing a robust approach for the future estimation of agglomeration benefits in Melbourne or even Australia.

Future research could also explore other measures of agglomeration effects apart from the two measures examined in this thesis. For instance, the CBD survey found that CBD employers are willing to increase their remuneration to compensate their workers for the CBD's poorer accessibility; wages and compensation may therefore offer alternative measures of agglomeration effects associated with urban rail congestion.

On the other hand, the survey findings seem to suggest that rising rail congestion not only has an employment suppression impact, it also drives up the wage cost in the CBD. Preliminary TERM modelling suggests that, should the wage hike persist in the long run, the employment impact is significant and this is likely to cause further deterioration in the CBD's productivity. This suggests that the productivity loss associated with an urban rail constraint may potentially be larger than those due to agglomeration effects. The interaction between wages, labour movement and productivity associated with rail congestion is an area that is not properly understood at this point in time and clearly warrants future research.

In addition, the CBD survey was conducted based on the employer stated and expected intentions. Future research could be conducted based on a Revealed Preference or Stated Preference approach to see how well the survey findings correlate with the actual situation. This may help to better understand the potential employment suppression impacts associated with rising rail congestion.

The secondary data analysis carried out in Chapter 7 was based on a sample size of 20 cities. Future work could be carried out to collect better quality data (for example more updated data based on better defined variables) for the analysis. In addition, future research should also expand the sample size and the number of independent variables (such as capacity provision of other public transport modes) to further improve the robustness of this approach.

As mentioned earlier, the TERM model used in this research incorporates Melbourne CBD into the Inner Melbourne region. To properly model the agglomeration impacts of an urban rail constraint on the CBD, it would be desirable to create an individual layer in TERM for Melbourne CBD. In addition, it may be worth considering creating individual layers to represent the major cities in Australia rather than consider them as a RoA (Rest of Australia) region. This would enable the CGE modelling approach to clearly distinguish whether the inter-regional flow-on effects go to the other major cities or other parts of Australia.

The preliminary work carried out on the wage shock approach suggests that TERM has the capacity to carry out greater simulations of the regional labour movement. As agglomeration effects are closely associated with labour movement, further work could be carried out in the use of TERM to examine how labour market effects could generate wider economic benefits for regions. Enhancement could also be made to the TERM model to introduce the generalised cost of work trips into the overall household consumption mechanism in TERM. This would permit the inclusion of work / home location choice into TERM for future transport-related applications and research.

In this research, the choices of rail commuters affected by the rising rail congestion are based on the work of HLB (2003). Future work (for example via a survey approach) could also be undertaken to examine how the travel behaviour of Melbourne rail commuters may change under circumstances of rail congestion. In particular, information on the whether the CBD rail commuters would give up their work trip and subsequently employment in the CBD should the rail congestion worsen would be useful. Such information would help in the future examination of the potential impacts associated with rail capacity constraint, in particular in MITM modelling.

In addition, future work could also be carried out to integrate observed changes in commuter travel behaviour into the MITM model. Conceptually, this would involve introducing a new element in MITM to govern the capacity of the various modes and a new sub-mode choice algorithm which captures how commuters would change their travel behaviour under circumstances of congestion. These enhancements to MITM could make it possible to endogenise such decision making process as part of the transport modelling framework in future. Model enhancement to build in carrying capacity of various modes into MITM may also be useful. This would enable MITM to better simulate how commuters would change their travel pattern should the carrying capacity of their desired mode choice be saturated.

Secondary research carried out by this study suggests that a land-use transport interaction model may offer a viable alternative to a CGE model to measure agglomeration effects associated with urban rail. However, to the best knowledge of the author, there is no readily available land-use transport model for metropolitan Melbourne. A possible area for future work may be to build such a model for Melbourne. The study could include the collection of the necessary data and the construction, calibration and validation of the model. The key contribution of such work would be to develop a land-use transport model that fully reflects the Melbourne land use and travel characteristics and use it to explore agglomeration effects and other labour market movement associated with a transport application in metropolitan Melbourne.

On a more ambitious scale, future study could also be carried out to integrate the TERM (or other ORANI – style) model with MITM and or even with a land-use transport interaction model. Conceptually, this would not only involve introducing generalised cost of work trips into the overall household consumption functions, the generalised cost of all trips would need to be integrated with the consumption functions of the various economic agents. For instance, the generalised cost of freight trips would need to be incorporated into the transport margin setting algorithm; the integrated land-use transport – CGE model could then simulate how the increase in transportation costs in say certain a highway corridor would affect the various industries in the respective regions and eventually the entire region's economy.

This research has made some important contributions to the knowledge of agglomeration economies associated with urban passenger by exploring a range of alternative methods, including a CGE modelling approach, to estimate such effects and examine their intra and inter-regional distribution. However, there remains immense potential in this field that awaits future work such as those suggested above. With the growing interest in urban rail projects globally, agglomeration benefits in urban rail is likely to gain rapid attention in the near future. A better understanding of agglomeration effects in urban rail is needed to aid estimation of their benefits for transport development projects into the future.

Appendix A
Congestion Status of Melbourne Train Network

This appendix presents the details of the calculation involved in the estimation of the rail capacity constraint status facing Melbourne CBD as discussed in Section 4.4.

Step (1) - Estimation of AM Peak Rail Capacity Supply

A total of 148 trains was available to operate the Metlink's timetable for the CBD that commenced operation in November 2008 as compared to the 134 trains that the operator had when Connex's operating franchise started in April 2004 (DOT, 2008a) Information from Connex Melbourne (2009) indicates the following growth of fleet size from 2004 to 2008:

- 2004 to mid 2005 – increased from 134 to 135 trains
- Mid 2005 to 4th quarter 2006 – increased from 135 to 140 trains
- 4th quarter 2006 to 3rd quarter 2007 – increased from 140 to 144 trains
- 3rd quarter 2007 to 4th quarter 2008 – increased from 144 to 148 trains.

DOT (2008a) and the VTP (DOT, 2009b) suggest that a total of 38 new trains are scheduled for delivery within the next few years. Information from Connex Melbourne (2009) suggests that the first of these 38 new trains arrived in late 2009; the remaining 37 new trains will be delivered between FY2010 to 2012.

The VTP also indicates that there is a longer term intention to further expand the fleet size by another 32 trains (DOT, 2009b). This is however not envisaged to take place in the next few years as there was no indicative time-frame given in the VTP and the rail operator is still awaiting collection of the remaining 37 new trains, as mentioned above.

Based on Metlink's (2008) train service timetables, all train services in the AM peak across the entire metropolitan network enters the CBD. This means that the total fleet size available to serve the Melbourne metropolitan area essentially serves Melbourne CBD.

As shown in Figure 4.8, a total of 173 services enter the CBD during the AM peak (Metlink, 2008). Communication with Connex Melbourne (2009) indicates that the 148 trains available for operation include 4 “standbys”. These figures suggest that the rail operator was able to run 173 services between 7 – 9am on an average weekday using 144 trains (i.e. 148 trains minus the 4 trains on standby) – this may imply that about 20% of trains (excluding those on standbys) were put through the network twice during the 7-9 am peak period.

Information from Connex Melbourne (2009) also suggests that, of the existing rolling stock, there are 7 Hitachi trains which were built in the 1970s. As these Hitachi trains have a shorter life expectancy than the new trains, this information from Connex Melbourne (2009) suggests that there is a possibility that some of these 7 trains may be retired from service with the arrival of the new trains. However, no further information regarding this issue is available.

In the absence of other information pertaining to the operating condition of the metropolitan train network, the following assumptions were made in this benchmarking assessment.

- 37 new trains would be introduced uniformly from FY2010 – 2012; the 32 new trains which are slated for longer term procurement as indicated in the VTP (DOT, 2009b) are not included in this assessment.
- 4 trains were put on standby (as per current operation) in the earlier years as well as in the future AM peak hours – this assumption was made on the basis that under the current rail operation, the various train lines will merge before reaching the city and form 4 line groups (Public Transport Division, 2008). Hence, this study considers it reasonable to assume that 1 train is put on standby for each line group.
- Of the remaining rolling stock available, 20% would also be put through the rail network twice in the AM peak hour so as to estimate the total number of rail services operated to serve the CBD between 7-9 am in a typical working weekday.
- The 7 Hitachi trains that were built in the 1970s will still be available for use in the short and medium term – this assumption is conservative for the purpose of this exercise as any removal of these 7 Hitachi trains will result in a higher estimation of the rail capacity constraint.

The total number of train services serving Melbourne CBD in the AM peak is estimated using Equation A1.

Total number of train services serving CBD in AM peak

*= (total fleet size – 4 "stand-by" trains)*120%* (Equation A1)

The total carrying capacity during the AM peak is then estimated using Equation A2 using an average maximum carrying capacity of 798 passengers per train as indicated in the Metropolitan Train Franchise tender documents (DOT, 2008b). The estimated rail capacities provided during the AM peak period from FY2004-05 to 2014-15 are presented in Figure A1.

Total rail capacity provided to serve the CBD in AM peak

= (total number of train services in AM peak) 798 passengers*

(Equation A2)

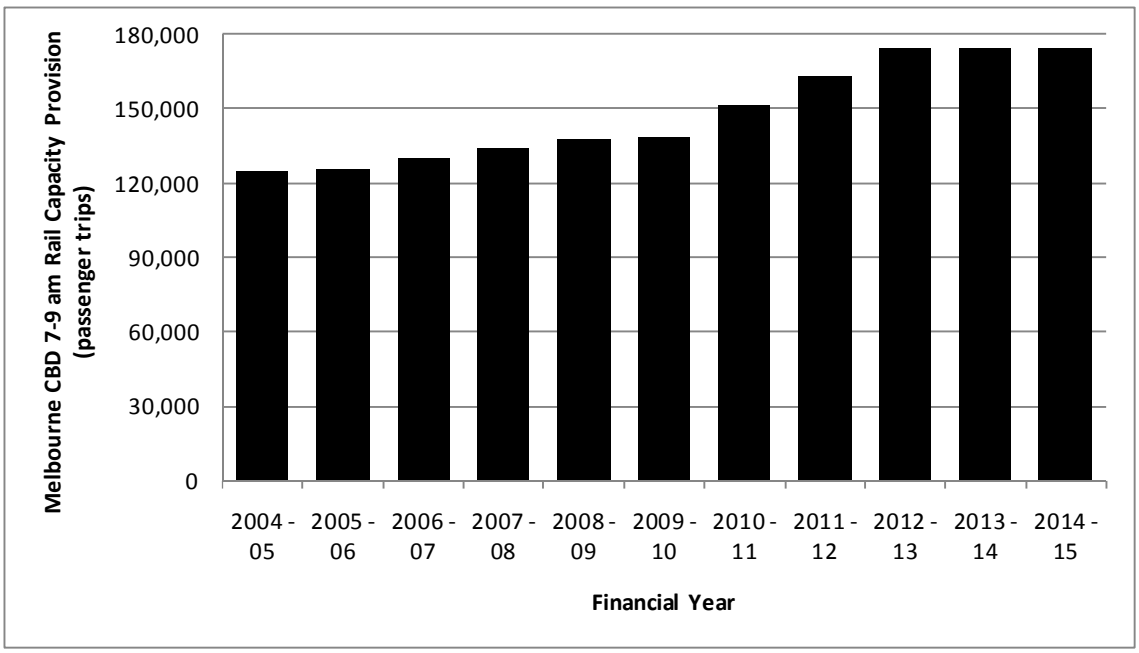


Figure A1: AM peak rail capacity provision from FY2004-05 to FY2014-15

As shown in Figure A1, there was an 11.5% increase in the rail capacity supply over the 5 years from 2004 to 2009 using the above assumption. With the delivery of the 37 new trains by 2012, the AM peak rail capacity provision is expected to be enhanced by a further 25%. Overall, AM peak rail capacity provision is estimated to grow about 40% from 2004 to 2012. This translates to an average growth rate of about 4.3% annually. If one only considers the growth for the next 5 years, the annual growth rate improves slightly to about 4.7%.

Step (2) - Estimation of AM Peak Rail Demand

DOT (2009a) reported an annual train patronage of 213.9 million boardings for FY2008–09. This is about 6% higher than the annual train boardings of 201.2 million reported for the previous year (DOT, 2008a). The annual patronage figures for the FY2004-05 to FY2006–07 were estimated from the annual patronage growth rate reflected in the respective DOT annual reports.

The annual train patronage volumes for FY2004-05 to FY2008-09 were then converted to average weekday patronage figures by applying an annualisation factor of 295 recommended by Connex Melbourne (2009). On the other hand, the daily ridership forecast for the next few years was estimated based on projections given in VTP (DOT, 2009b) as shown in Figure 4.13.

The 7-9am peak hour train ridership was then estimated based on these daily rail patronage figures and information from Connex Melbourne (2009) - according to Connex Melbourne (2009), the 7-9am peak accounted for some 28% of the daily patronage for an average working weekday. Of these, about 90% occurs in the peak direction heading towards the CBD. Based on these parameters, the AM peak rail demand for the CBD-bound train services was estimated using Equation A3. The results are presented in Figure A2.

AM peak rail demand in the direction of the CBD

*= (Annual train patronage volume / 295) * 28% * 90%* (Equation A3)

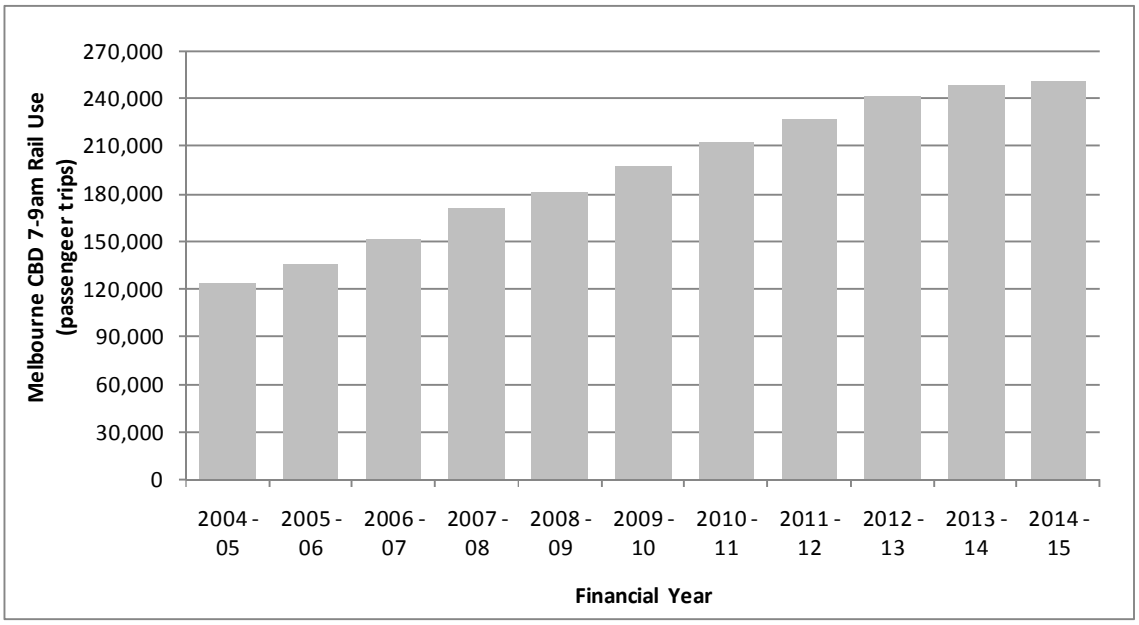


Figure A2: AM peak rail demand from FY2004-05 to FY2014-15

As shown in Figure A2, AM peak rail demand has increased steadily over the last few years and is envisaged to grow further in the future. Figure A2 suggests that the AM peak rail demand for trains entering the CBD has grown by about 47% over the last 5 years. This translates to an annual growth rate of about 8%. DOT (2009a) explained that this high growth in the AM peak rail patronage over the last few years could be due to several reasons such as the rising petrol cost over the last few years that pushed many drivers to switch to the rail mode, higher CBD employment level, higher parking costs in the CBD and even more train services.

Based on the daily train patronage projections given in the VTP (DOT, 2009b), AM peak patronage is envisaged to increase by another 37% over the next 5 years or about 6.5% annually. The slower growth rate in AM peak rail demand anticipated for the next few years (as compared to the last few years) could possibly be due to the current global economic crisis which is expected to slow down employment growth or lower the employment level in the CBD – rail demand is expected to decline in tandem with weaker employment level. On the other hand, the higher level of rail congestion (possibly due to more car users switching to the train mode so as to cut travelling expenses under the current financial crisis) may also have a peak-spreading effect where more commuters choose to travel outside the AM peak period.

Step (3) - Estimation of AM peak rail capacity constraint status

The status of urban rail capacity constraint (i.e. how much rail demand exceed capacity provision) facing Melbourne CBD in the AM peak was estimated by comparing the output from Step (1) and (2) using Equation A4. The results are presented in Figure A3. The analysis of the findings is presented in Section 4.4.2.

AM peak rail capacity constraint

= (AM peak rail demand – AM peak rail provision) / (AM peak rail provision)

(Equation A4)

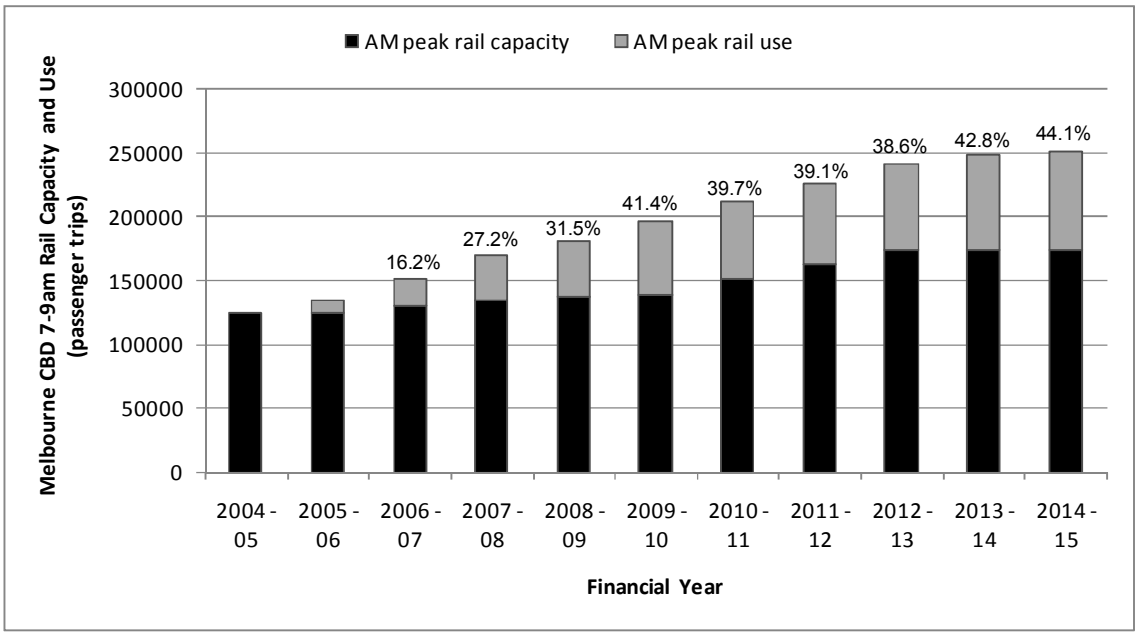


Figure A3: AM peak rail congestion level facing Melbourne CBD

(FY2004-05 to FY2014-15)

Appendix B
Comparative Assessment of Australian CBDs

This appendix presents the details of the comparative assessment of Melbourne CBD against the CBDs of Sydney, Adelaide, Perth and Brisbane Local Government Areas (LGA) as discussed in Section 4.6.

In the course of gathering information for this assessment, it was found that unlike Melbourne and Sydney LGA which each has a well-defined CBD, both Adelaide and Perth have (in their terminology) a Central Business Zone or Area which represents the nucleus of the employment within the respective City's LGA (Adelaide City Council (2009) and City of Perth (2009)). Therefore, this analysis adopted the employment and rail capacity for the Central Business Zone of these cities as the CBD proxy.

The approach adopted in this assessment to estimate the AM peak rail capacity provision and use for the other CBDs is similar to for Melbourne CBD as presented in Appendix A. Details of these computations are presented below.

Step (1) - Estimation of AM Peak Rail Capacity Provision

The total rail carrying capacity serving Melbourne CBD was estimated as explained in Appendix A. The total number of train services that serve the other CBDs were derived from the respective train timetables for each city. The average maximum carrying capacity per train service for their rail systems were obtained from the following sources:

- **Sydney CBD** –
  CityRail (2009a) indicates that a typical peak hour train serving Sydney CBD has the average maximum carrying capacity of 1,242 passengers;

- **Brisbane CBD** –
  Brisbane CityTrain (2009a) indicated that a typical train service serving Brisbane CBD can carry an average maximum of 750 passengers;

- **Perth CBD** –

  TransPerth (2009a) indicated that their current rolling stock include 48 two-car trains (carry capacity of 312 passengers) and 32 three-car trains (carrying capacity of 560 passengers); the information suggests that the (weighted) average maximum carrying capacity per train service serving Perth CBD in the AM peak is about 410 passengers; and

- **Adelaide CBD** –

  The information obtained from TransAdelaide (2009a) suggests that the (weighted) average maximum carrying capacity per train service during the AM peak for Adelaide is about 254 passengers.

The total rail carrying capacity serving each CBD was then estimated via the product of the total number of train services entering the CBD and the average carrying capacity per train service. The results are shown in Table B1 below.

Table B1: Overall rail capacity serving the various CBDs in AM peak (2006)

CBD	Melbourne	Sydney	Brisbane	Perth	Adelaide
Total no. of train services that goes into the CBD between 7-9am	173	166	90	91	51
Average maximum rail carrying capacity per train service (7-9am)	798	1,242	750	410	250
Estimated total rail carrying capacity serving the CBD (7-9am)	138,000	206,200	67,500	37,400	12,800

Source: Developed from information from Metlink (2008), DOT (2008b), CityRail (2009a, 2009b), Brisbane CityTrain (2009a, 2009b), Transperth (2009a, 2009b) and TransAdelaide (2009a, 2009b)

Step (2) - Estimation of Overall AM Peak Rail Capacity Use

Table B2 also shows the total employment and the corresponding rail demand for each CBD in the AM peak.

Table B2: Overall rail capacity use for the various CBDs in AM peak (2006)

CBD	Melbourne	Sydney	Brisbane	Perth	Adelaide
Total CBD employment (2006 figure)	200,500	230,000	104,750	61,800	66,700
CBD area (km^2)	3.5	4.2	2.5	2.0	3.8
CBD employment density (employees / km^2)	56,600	55,400	41,900	30,900	17,500
Rail Mode Share for CBD work trips	48%	47%	28%	22%	9%
Total amount of CBD rail trips carried out between 7-9am	87,000	82,800	26,600	12,300	5,400

Source: Developed from information from ABS (2006d, 2006k, 2009a, 2009b, 2009c), City of Melbourne (2006), Melbourne City Council (2003), TDC (2008, 2009a, 2009b), City of Perth (2009), Brisbane City Council (2006), Adelaide City Council (2009) and Transport Research Centre (1999).

The details of each CBD and their rail mode share were gathered through the following sources:

- **Melbourne CBD** –

  CBD employment figures were from CLUE (City of Melbourne, 2006) while the total CBD area was based on information from Melbourne City Council (2003); CBD's rail mode share was estimated based on data from a customised report from the Australian Bureau of Statistics (ABS) (2009c).

- **Sydney CBD** –

  CBD employment figure and area as well as the rail mode share was based on information from by TDC (2008, 2009a, 2009b).

- **Brisbane and Adelaide CBD** –

  the total employment and rail mode share of both CBDs were estimated using information from customised ABS reports - ABS (2009a, 2009b); CBD area was estimated using the boundaries given by Brisbane City Council (2006) and Adelaide City Council (2009).

- **Perth CBD** –
  the total CBD employment and area as well as rail mode share was estimated using data from ABS (2006d) and ABS (2006k) and the CBD boundary definition provided by City of Perth (2009).

VATS data (Transport Research Centre, 1999) suggests that about 75% of the work-related rail trips going into Melbourne CBD are made during 7-9am on a typical weekday and that work-related rail trips made up some 83% of the total amount of rail trips that go into the CBD in the morning peak of a weekday. As corresponding information for Brisbane, Perth and Adelaide CBD are unavailable, Melbourne's values were adopted for these CBDs.

Both these factors as well as the rail mode share were then applied to the total CBD employment to yield the total amount of CBD bound rail trips carried out between 7-9am on a typical weekday - i.e.

$$\text{Total CBD rail trips (7-9am)} = \left(\text{Total CBD Employment} * \text{Daily rail mode share} * 75\%\right) / (83\%) \qquad \text{(Equation B1)}$$

For the case of Sydney, information from Transport Data Centre (TDC) (2009a) suggest that about 66% of the work-related rail trips going into Sydney CBD are made during 7-9am on a typical weekday. In addition, TDC (2009a) also indicated that work-related rail trips made up some 88% of the total amount of rail trips that go into the CBD in the AM peak of a weekday. These values were applied to Equation B1 to estimate the overall rail demand for Sydney CBD in the AM peak.

Using Equation B1, it was estimated that about 87,000 rail trips were made into Melbourne CBD in the AM peak. To check the robustness of this approach, an assessment was carried out to assess the reasonableness of the estimates for Melbourne CBD.

According to Connex Melbourne (2009), the trips made during 7-9am peak hours accounted for 28% of the daily patronage of 720,000 for an average working weekday on Melbourne Metropolitan train network. This suggests that presently, some 201,600 rail trips are made in trains in the AM peak. According to VicRoads (2008a), of all the journey-to-work trips made in Melbourne metropolitan area using public transport, 42% ends in Melbourne CBD – see Table 4.1 (page 110). This implies that of the 201,600 rail trips made in the AM peak, about 84,700 rail trips are CBD-bound trips. This figure is fairly close to the 87,000 trips estimated using Equation B1 which suggest that the above methodology is reasonably robust.

Step (3) - Comparative Assessment of Australian CBDs

Table B3 shows the AM peak rail loading factor for the various CBDs. To reiterate, the rail loading factor is the ratio of the total CBD rail demand and the total rail capacity provided in the AM peak. In other words, the AM peak loading factor measures the average occupancy of the train system going into each CBD between 7-9 am on a typical weekday; this gives an indication of the utilisation level of the train systems serving the CBD.

Table B3: Rail loading factor for various Australian CBDs (2006)

CBD	Melbourne	Sydney	Brisbane	Perth	Adelaide
Total rail carrying capacity serving the CBD between 7-9am of a typical weekday	138,000	206,200	67,500	37,400	12,800
Total amount of rail trips entering the CBD between 7-9am of a typical weekday	87,000	99,800	26,600	12,300	5,400
Average AM Peak Rail Loading factor	**0.6**	**0.5**	**0.4**	**0.3**	**0.4**

Results of the comparative assessment are presented in Section 4.5.2.2.

Appendix C

Field Survey Report – Melbourne CBD Employer Survey

C1. Introduction

C1.1 Introduction

This report presents the field survey report of the Melbourne Central Business District (CBD) employer survey which was conducted as part of this PhD research.

C1.2 Report aims

The main aim of this report is to detail the survey design, implementation and the results of the Melbourne CBD employer survey. Analyses of the results are presented in the main thesis.

C1.3 Report structure

The report is structured as follows:

- Section C2 – Survey Design and Development – describes the aim of the survey, the form and types of the questionnaire and how the survey was conducted;
- Section C3 – Survey Conduct and Outcomes – describes the outcomes of the survey program;
- Section C4 – Survey Findings – presents the key observations and results;
- Section C5 – Conclusion; and

Attachment 1 – Complete set of the survey questionnaire

C2. Survey Design and Development

C2.1 Introduction

This section describes the aim of the survey, the form and types of the questionnaire and how the survey was conducted.

C2.2 Survey aim

The objective of the survey was to gather information from the CBD employers regarding the potential impact that rail congestion may have on their business costs. The survey findings would be used as inputs in the next stage of research involving CGE modelling to estimate the economic impact to Melbourne CBD.

C2.3 Survey approach

Overall, this stage of research comprises six steps as shown in Figure C1:

- Literature review
- Sample size and survey questionnaire development,
- Ethics clearance,
- Pilot survey,
- Survey execution and monitoring; and
- Result analysis and documentation.

The original intention of this research was to enlist the assistance of major organisations to help advertise the web-based survey. Organisations that were considered suitable for this purpose included those that have a large network of members who own businesses in the CBD such City of Melbourne and the Victorian Employers' Chamber of Commence and Industry (VECCI). However, despite several months of active follow-ups, the organisations cited survey fatigue or no interest to be involved in research during this period of poor economic climate as the key reasons for not willing to render assistance. Only GoingSolar, an organisation involved in public transport promotion agreed to help advertise the survey.

A direct telephone call invitation approach was subsequently adopted for the survey. This approach was chosen as it enabled the CBD companies to be reached directly at the shortest time and the lowest cost possible.

The survey was conducted as follows:

1. Potential participants were identified from Telstra's (2009) businesses telephone directories. On average, companies from one sector were targeted each day.
2. The companies were invited via telephone calls to participate in the survey. The invitation was directed to the Human Resource Managers or any individual in a similar capacity that has ample knowledge of how the firm's remuneration packages or employment plans is likely to change in the near future.
3. A follow up email that contained the explanatory statement of the project and the web-link to the survey in the SurveyMonkey website was sent to the companies that are willing to consider participating.
4. Survey responses were collected via the SurveyMonkey platform.
5. The response rate was monitored daily so that any industry that falls short in terms of desired participation rate would be targeted again.

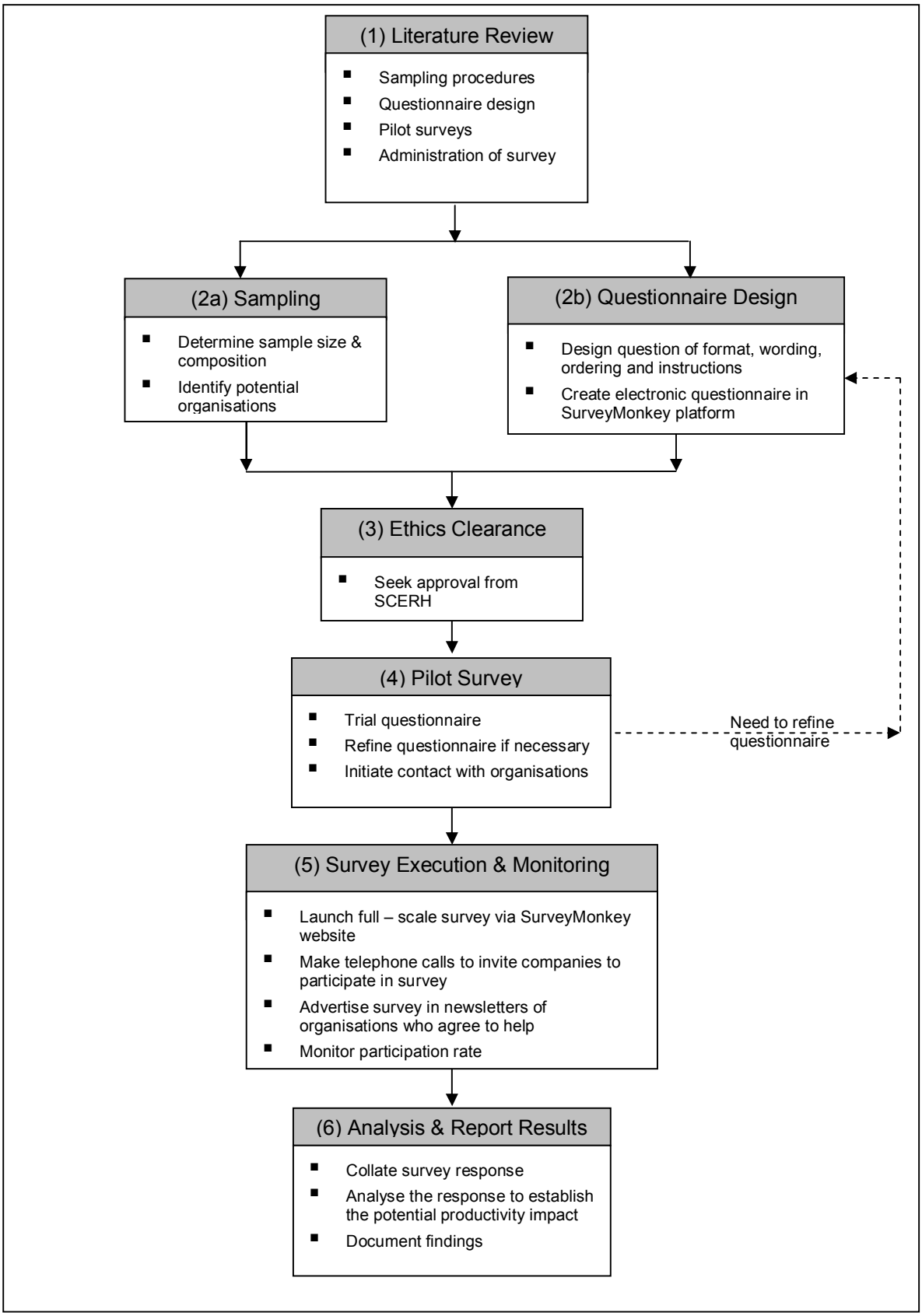


Figure C1: Melbourne CBD employer survey methodology

C2.4 Pilot survey

This approach was first used for a pilot survey of 12 participants before being adopted in the main survey exercise. The pilot survey involved 12 participants including eight academics and consultants with experience in planning and execution of surveys as well as four existing CBD employers. The pilot test enabled evaluation of all aspects of the survey including:

- Invitation-to-participate process
- Question wording and flow
- User-friendliness of the electronic questionnaire
- Data outputs

Results and feedback from the pilot are explored in section 3.2.

C2.5 Sample size and composition

According to Neuman (1991), there are basically two ways to ascertain the desired sample size of a survey exercise:

- To make assumptions about the population and use statistical means to work out the appropriate sample size; or
- To estimate the sample size using rules-of-thumb – which are based on past studies that have met the requirements of statistical methods.

Neuman (1991) highlighted that researchers frequently used the rules-of-thumb method to derive sample size as they rarely have the information required by statistical methods and because the resultant sample sizes are close to those estimated using statistical methods. Neuman (1991) recommended that for large populations (over 150,000), a sampling ratio[1] of about 1% is acceptable to yield a representative sample.

The rules-of-thumb method was adopted to ascertain the sample size for the survey. According to the CLUE data (City of Melbourne, 2006), Melbourne CBD currently employ about 200,500 employees. Based on the rules-of-thumb, a sample size which contains the number of firms that employ a total of 2,000 employees would be acceptable for this survey – i.e. 1% of 200,500 employees.

[1] Neuman (1991) defined the sampling ratio to be the ratio between the sample size and the population size.

The targeted participation level of each industry type in the survey was estimated using the 2006 actual employment figures from CLUE (City of Melbourne, 2006) – see Table C1. This was based on the total number of workers employed in the sector expressed as a percentage of the total CBD employment.

Table C1: Targeted participation rate across sectors

Industry Type	2006 employment	Participation Target
Business and Management services	47,139	25%
Finance and Insurance	41,542	22%
Public Admin/Edu/healthcare	35,114	19%
IT services	19,508	10%
Hotel and Food services	16,861	9%
Retail and wholesale	15,738	8%
All other services	10,802	6%

Actual participation rate of the various sectors are reported in section C3.3 of this report.

C2.6 Questionnaire design

C2.6.1 Contents of questionnaire

The questionnaire was designed to gather inputs on the following 3 aspects of the CBD businesses:

i. The business details (such as the industry the business belongs to) and the employment demographics (such as staff strength) of the firm,
ii. The firm's willingness-to-pay (via increased remuneration) for various degree of traffic congestion; and
iii. The impact of traffic congestion to their future employment plans in the short term and decision to continue to stay within the CBD should the traffic congestion worsen in the longer term.

The questions were arranged to guide the participants to first consider the profile of his employees and their travel behaviour. This is to set the stage to seek the participant's view on how rail capacity constraint might impact their business costs.

Output from the earlier MITM traffic scenario testing was used to illustrate hypothetical traffic scenarios in the survey questionnaire. Possible journey times to work in the CBD under different degrees of rail capacity constraint were painted to the participants. This is to help the participants appreciate the impact of rail constraint on work trip travel times and assist them to estimate the potential implication of the increased travel times on their business costs and location decisions.

C2.6.2 Length of questionnaire

The length of the survey was kept to one that can be completed comfortably within 10-15 minutes. This was based on the work of Stopher (as cited in Richardson et al.(1995)) which indicated that the overall response rate of telephone interviews dropped rapidly after 10-15 minutes. While the survey method examined by Stopher (as cited in Richardson et al. (1995) was not identical to that adopted for this survey, his findings may offer an indication of the respondent's attention span during survey.

C2.6.3 Range of industries to include in questionnaire

The first section of the survey questionnaire was intended to gather basic information regarding the firm that is being surveyed. One of the questions relates to industry type. A check with CLUE (City of Melbourne, 2006) indicates that CLUE classifies industries into some 20 categories while the standard version of the ORANI model distinguishes some 112 industries (Dixon et al., 2002a). Such high level of industry-type disaggregation cannot be operationalised in the survey questionnaire as it is likely to confuse the participants. According to Richardson et al. (1995), as a general rule-of-thumb, it is good survey practice to limit the number of response categories to 7.

Bearing this rule-of-thumb in mind, 7 industry categories were proposed in the survey questionnaire:

1. Finance and Insurance,
2. Business and Management services,
3. Hotel and food services,
4. Retail and Wholesale,
5. Public Administration and Safety, Education/Training, Healthcare and Social assistance,
6. Information media and telecommunication services; and

7. All other services (including Administration & Support, Hiring / Rental, Arts and Recreational services)

These seven industry categories are derived based on the following considerations:

- To include the major industry types (and hence employment sectors) in the CBD which has a knowledge-based economy – according to CLUE (City of Melbourne, 2006), these 7 categories would already cover more than 93% of the total employment in the CBD,
- To ensure the compatibility of the survey findings for subsequent use in the ORANI model – i.e. there must be sufficient degree of segregation and flexibility to only "shock"[2] the concern industries in the economy; and
- To avoid confusion and ambiguity by keeping the classification clear and mutually exclusive.

A copy of the survey questionnaire is provided in Attachment 1. Results of the survey are discussed in section C4.

C2.7 Ethics

The Monash University Standing Committee on Ethics Research Involving Humans (SCERH) reviews all research conducted by the university that involves human participation. It is a standard requirement of Monash University and Australian Research Council that all research conducted by agencies comply with the ethical requirements of SCERH. Ethical approval was sought and granted (approval number 2009000622) in May 2009.

In accordance with the ethics process, participants voluntarily opted-in to the project. An explanatory statement was created to ensure that participants were fully informed about the nature of the project. Those participants who consented to participate in the survey can click on the provided web-link to start the survey.

[2] In CGE terminology, the process of inputting any impact into the economic model so as to simulate its impact to the economy is known as a "shock" (Dixon et al., 2002a).

C3. Survey Conduct and Outcomes

C3.1 Introduction

This section concerns the general survey conduct outcomes of the pilot and main survey. The pilot survey was undertaken between 25thMay and 26th Jun 2009. The main survey commenced on 10th August 2009 and finished on 30th September 2009.

C3.2 Pilot survey

A pilot survey of 12 participants was carried out to test the opt-in process, questionnaire and user-friendliness of the electronic questionnaire in the SurveyMonkey website.

A key feedback from the pilot test suggests that given the uncertainty, employers are not likely to be able to give a reasonable indication of how their long term remuneration and employment plans may be affected by the rising rail congestion. The relevant questions were therefore amended for the main survey. Apart from this, there were also some minor comments which were also implemented for the main survey. The overall changes included:

- A confidentiality clause regarding the storage and use of the survey responses was added to the electronic questionnaire to reassure the participants,
- Amendments to Questions 13 and 15 to capture only the effects for the short term (i.e. from 2009 – 2011),
- An “Any other comments” question was added to the end of the questionnaire; and
- Minor changes to the wording and the order of some of the questions were made to improve the flow of the questionnaire and correct errors.

C3.3 Main survey

The main survey was conducted between 10th August and 30th September 2009. The survey process went according to the procedures established in the pilot test. Overall, about 600 telephone calls were made and 250 emails were sent. In addition, the survey was advertised for about 3 weeks in the GoingSolar's "Sustainable Cities and Transport" Newsletter issues 122, 123 and 124 which ran between 8th to 23rd September 2009.

A total of 65 companies eventually participated in the survey. Table C2 shows the number of companies in each sector that participated in the survey as well as their total employment.

Table C2: Short term employment impacts across sectors

Sectors	Total no. of companies that participated in survey	Total employment of companies
Finance & Insurance	11	290
Business Management Consultants	17	309
Food & Hotel	6	72
Wholesale & Retail	6	93
Public Admin / Healthcare / Social services	9	183
Information Technology services	11	92
Rental & Hiring / Recreational services	5	71
Total	65	1,110

Based on number of telephone calls made, the result yielded a final opt-in rate to the survey of about 11%. The 65 companies employ a total of 1,110 employees which translated to a sample size of about 0.6% of CBD employees.

Figure C2 shows the targeted and actual survey participation rate across industries. As shown in Figure C2, the main survey sample is a reasonable representation of the actual CBD workforce in terms of industry distribution.

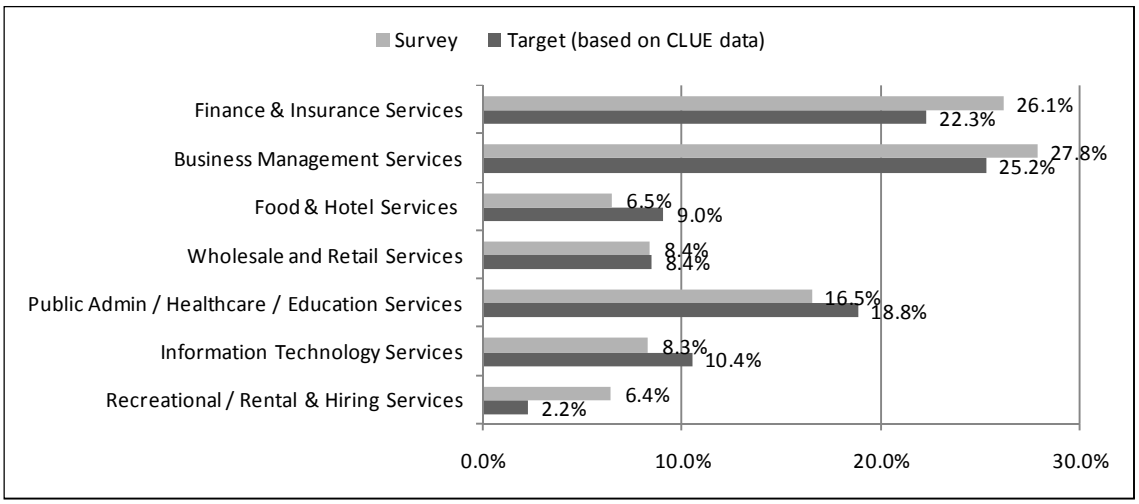


Figure C2: Targeted and actual participation rate

C4. Survey Findings

C4.1 Introduction

This section presents the key observations and results from the survey. It does not include the detailed analysis of the survey results which are presented in the main thesis (Chapter 6).

This section is divided into the following parts:

- Key observations and feedback;
- Remuneration impacts;
- Short term employment impacts; and
- Long term employment impacts

C4.1 Key observations and feedback

In the course of conducting the main survey, the following observations / feedback were made / received:

- Major organisations such City of Melbourne and VECCI have indicated that CBD companies and workers are constantly being bombarded by surveys. They highlighted that even their own surveys are not well-received by the CBD firms due to survey fatigue. Hence, they anticipate that the CBD employers are not likely to participate actively in surveys especially those that are carried out as part of postgraduate research programmes.

- The TDM group whose members include representatives from several major companies located in the CBD have responded that the group is not interested during this period of economic uncertainty to participate in research. This view was shared by the other major companies in the CBD that this project contacted directly. The general consensus of these companies was that the media has drastically under-reported the impact of the current global economic crisis; their sole focus at present time was to do business to improve their firms' performance. This also explains the high rejection rates (to participate) especially amongst the bigger firms.

- Larger firms have also shown less interest in participating in the survey because their client market is largely located within the CBD and they will not shift out of the CBD regardless of traffic congestion levels - this was one of the main reasons for refusal to participate given by the larger companies.

- In addition, the bigger firms especially those in the professional fields have also highlighted that the skill sets and expertise of their employees are largely required by jobs found within the CBD. Hence regardless of the congestion level, these professional employees would still work in the CBD. These larger firms therefore have less concern about rising traffic impact on their employment plans and business costs.

- Several Human Resource Directors / Managers as well as recruitment firms have reflected that the current economic situation has essentially created “an employers’ market”. Hence the employers hold the view that they have the upper hand in not having to worry about losing their staff to the rising cost of commuting. This may have lowered the CBD employers’ participation rate especially the larger firms.

- Recruitment firms have also suggested that larger firms have natural attractiveness (such as better staff development programmes) to retain and attract staff and coupled with the “employers’ market” environment, larger firms are generally not worried about CBD congestion impact on their employment plans.

- The small and medium size firms on the other hand, tend to be more willing to participate in the survey because their smaller work force means that losing staff to congestion impact (for example the staff is late for work due to traffic congestion or decided to find a job closer to home) is more detrimental to their overall business operation. In addition, the smaller firms are also less competitive in terms of remuneration packages compared to the bigger players. Hence they showed more interest in retaining or attracting new staff. This is evident in the survey results.

- The survey results showed that about 10% of the surveyed companies are willing to consider relocating out of the CBD. Since most of the companies that participated in the survey are the small and medium establishments, the result suggests that companies of these sizes may be more willing than the big firms to move out of the CBD.

- The surveyed companies have provided feedback that should they relocate out of the CBD, the fringe of the CBD would be their preferred choice as their client market is largely located within the CBD. This suggests that the client base of firms is a major factor that influences the location decisions of companies.

C4.2 Remuneration impacts

The survey responses indicated that slightly more than half (52%) of the surveyed firms (based on total employment) are willing to consider increasing their remuneration packages to retain or attract new staff when accessibility to the CBD during the AM peak hour becomes more difficult – see Table C3.

Table 3 shows the number and percentage of firms (based on total employment of firm) that have indicated that they are willing to increase their remuneration package to attract or retain staff. The responses suggest that firms in the Food and Hotel, Wholesale and Retail as well as the Recreational / Rental and Hiring sectors are more willing to increase their remuneration package to retain staff while those in the Public Admin / Healthcare / Social services and the Business Consultancy sectors are less willing. There was however no observable correlation between the size of the firm and their willingness to increase remuneration to retain / attract staff.

Table C3: Remuneration impacts across sectors

Sectors	Total no. of companies that participated in survey	No. of companies that are prepared to increase remuneration	% of companies that are prepared to increase remuneration (based on employment)
Finance & Insurance	11	4	62%
Business Management Consultants	17	5	30%
Food & Hotel	6	5	92%
Wholesale & Retail	6	5	92%
Public Admin / Healthcare / Social services	9	4	22%
Information Technology services	11	6	57%
Rental & Hiring / Recreational services	5	3	77%
Total	65	33	52% (weighted average)

The results shown in Table C3 may be possibly because for the Food and Hotel, Wholesale and Retail as well as the Recreational / Rental and Hiring sectors, majority of their workforce are lower income earners such as labourers, workers and technicians. These workers have more employment mobility since their skill set is not highly specialised and they can find another similar job in other employment centres should the commuting to the CBD becomes more difficult. Hence these sectors are more willing to increase their remuneration to retain staff.

On the other hand, the employees in the Business Consultancy sector are largely professionals. These professional firms have provided feedback that the skill sets and expertise of their employees are required largely in the CBD. Hence regardless of the congestion level, these professional employees would still work in the CBD. This may explain the lower inertia for the employers in these sectors to consider increasing the remuneration to retain or attract new staff when congestion level rises.

The Public Administration sector has also indicated that their operational costs are largely governed by State Government funding. Hence they do not have the capacity to increase remuneration when commuting costs rises.

A similar trend is observed when the amount of increment in remuneration that the various sectors are willing to pay is examined – see Table C4. The survey responses suggest that not only the Food and Hotel, Wholesale and Retail and the Recreational / Rental and Hiring sectors are more willing to increase their remuneration to retain staff, they are also willing to increase it by a larger percentage compared to those firms in the Public Admin / Healthcare / Social services and the Business Consultancy sectors.

The higher willingness-to-pay of the first group of sectors could be due to the generally lower wages that the workers in these sectors are currently being paid compared to those professionals working in the Finance and Insurance as well as the Business Management Consultancy services.

As shown in Table C4, the Recreational / Rental and Hiring sectors are willing to increase their remuneration by the largest magnitude while the remuneration increment indicated by the Public Admin / Healthcare / Social services are the lowest. The large magnitude of remuneration compensation indicated by the Recreational / Rental and Hiring sectors may be due to the comparatively lower base salaries or higher mobility of the workers in these industries. On the other hand, the funding constraint of the Public Administration sector which made up the largest proportion of this group may explain why this group of industries are only willing to increase remuneration by the smallest margin when commuting cost increases.

Table C4: Magnitude of remuneration impacts across sectors

Sectors	Remuneration impact for 10% rail capacity constraint	Remuneration impact for 30% rail capacity constraint
Finance & Insurance	1.95%	3.27%
Business Management Consultants	1.20%	2.56%
Food & Hotel	3.49%	6.47%
Wholesale & Retail	2.63%	5.45%
Public Admin / Healthcare / Social services	1.31%	2.27%
Information Technology services	2.61%	4.20%
Rental & Hiring / Recreational services	5.72%	9.08%
Weighted average	2.09%	3.75%

Overall, the survey results suggest that CBD employers are willing to increase remuneration by a weighted average of about 2.09% under traffic congestion associated with 10% rail capacity constraint. At higher congestion level associated with 30% rail capacity constraint, the survey results suggest that the CBD employers are willing to raise remuneration further by about 3.75% (weighted average).

The remuneration impact of the 30% rail capacity constraint scenario is about twice that of the 10% rail capacity scenario although the corresponding capacity constraint is three fold. This is possibly due to the way the questionnaire is structured as it was reflected hypothetically in the survey that the 10% rail capacity constraint would increase automobile travel times into the CBD during the AM peak by about 15% on average; the average impact of the 30% rail capacity constraint is a 25% increase in automobile travel time during the AM peak.

C4.3 Short term employment impacts

In terms of potential employment impacts, about one-third (27%) of the surveyed companies indicated that rising traffic congestion may have some impact on their short term employment plans. Table C5 shows the percentage of firms (based on total employment) that have indicated that the rising traffic congestion may have a detrimental impact on their short term employment plans.

Table C5: Short term employment impacts across sectors

Sectors	Total no. of companies that participated in survey	No. of companies that may suffer short term employment impacts	% of companies that may suffer short term employment impacts (based on employment)
Finance & Insurance	11	3	13%
Business Management Consultants	17	4	24%
Food & Hotel	6	3	57%
Wholesale & Retail	6	5	41%
Public Admin / Healthcare / Social services	9	3	17%
Information Technology services	11	4	46%
Rental & Hiring / Recreational services	5	3	44%
Total	65	25	27% (weighted average)

The responses suggest that the employment plans of firms in the Food and Hotel, Wholesale and Retail as well as the Recreational / Rental and Hiring sectors are more likely to be affected by the increasing traffic congestion while those in the Public Admin / Healthcare / Social services and the Business Consultancy sectors may suffer a smaller employment impact.

Again, the responses seem to reinforce the earlier suggestion that the first group of sectors where the majority of their workforce are non-professionals are more likely to be affected should the CBD traffic condition deteriorate. This is because the lower skilled workers have more employment mobility since their skill set is not highly specialised and they are able to find similar job in other employment centres should the commuting to the CBD becomes too difficult.

On the other hand, the employees in the Business Consultancy sector are largely professionals and as highlighted earlier, these professional firms have provided feedback that the skill sets and expertise of their workers are required largely in the CBD. Hence regardless of the congestion level, these professional employees would still work in the CBD; this may explain why these sectors are more immune to the detrimental effects of rail congestion on their future employment plans in the short term.

A similar trend is observed when one examines the magnitude of employment impact – see Table C6. The magnitude of employment impact for each participating firm was estimated by taking the difference between the employers' employment projection for the next 2 years with and without consideration of the hypothetical traffic scenarios (i.e. between the responses to Question 10 and 15). The figure shown in Table C6 for each sector is a weighted average figure based on the employment of the participating firms.

The Food and Hotel, Wholesale and Retail and the Recreational / Rental and Hiring sectors are not only more susceptible to higher traffic congestion, their employment impact are also higher compared to the Public Admin / Healthcare / Social services and the Business Consultancy as well as Finance and Insurance sectors. Again, this is likely to be due to the comparatively lower employment mobility of the workers in the latter group of sectors.

Table C6: Magnitude of employment impacts across sectors

Sectors	Employment impact for 10% rail capacity constraint	Employment impact for 30% rail capacity constraint
Finance & Insurance	0.69%	1.52%
Business Management Consultants	0.66%	1.39%
Food & Hotel	1.81%	3.63%
Wholesale & Retail	2.04%	3.12%
Public Admin / Healthcare / Social services	0.74%	1.38%
Information Technology services	1.29%	2.45%
Rental & Hiring / Recreational services	1.42%	2.32%
Weighted average	0.97%	1.86%

In general, results shown in Table 5 and 6 suggest that those sectors that are willing to consider higher remuneration packages when traffic condition deteriorates are also the ones that are more likely to indicate that the rising congestion may also affect their employment plans in the short term.

Overall the survey results suggest that a 10% rail capacity constraint may be associated with a short term CBD employment impact of about 0.97% (weighted average). On the other hand, a 30% rail capacity constraint may be associated with a 1.86% (weighted average) reduction in the CBD's employment in the short term.

It is observed that the employment impact of the 30% rail capacity constraint is about twice that of the 10% rail capacity constraint despite the corresponding capacity constraint being three times higher. As highlighted earlier, this outcome is possibly due to the information provided under the hypothetical scenarios in the survey.

C4.3 Longer term employment impacts

The survey did not explicitly capture the employment suppression impact associated with rising rail congestion for the longer term. As explained in Section C3.2, this is because feedback during the survey pilot test suggests that given the uncertainty, employers are not likely to be able to give a reasonable indication of how their long term remuneration and employment plans may be affected by the rising rail congestion. Therefore, this research used the survey to obtain an indication of the probability that CBD firms may relocate out of the CBD in the longer term due to rising rail congestion.

About 11% of the surveyed companies indicated that they would consider moving out of the CBD in the longer term should the CBD traffic condition deteriorate in the future. Table C7 shows the proportion of companies in each sector that may consider a possible relocation out of the CBD in the longer term.

Table C7: Number of companies across sectors that may relocate out of CBD in the longer term

Sectors	Total no. of companies that participated in survey	No. of companies that may relocate out of the CBD in longer term	% of companies that may relocate out of the CBD in longer term (based on employment)
Finance & Insurance	11	2	3%
Business Management Consultants	17	2	3%
Food & Hotel	6	1	11%
Wholesale & Retail	6	1	5%
Public Admin / Healthcare / Social services	9	2	44%
Information Technology services	11	1	7%
Rental & Hiring / Recreational services	5	0	0%
Total	65	25	11% (weighted average)

For all the sectors except the Public Admin / Healthcare / Social service and the Food and Hotel services sector, less than 10% of the surveyed firms have expressed a willingness to consider relocating out of the CBD in the longer term should traffic congestion increases. In particular, the Recreational / Rental and Hiring firms surveyed expressed that they will not move out of the CBD regardless of the future traffic situation. Feedback from these sectors suggests that they will not move out of the CBD as there will always be a demand for their services in the CBD – for example a car rental firm indicated that there will always be a need for them to have an outlet in the CBD to make it easier for their customers to pick-up or drop off the rental cars. This may also explain why these industries have previously indicated the highest remuneration increase to pay to retain or attract new staff when traffic congestion increases.

Slightly more than 40% of the Public Admin / Healthcare / Social service industries have indicated a possible relocation out of the CBD in the longer term. The details of the survey responses suggest that the exceptionally high rates for this group is because one of the participants which is prepared to move to the fringe of the CBD in the longer term is a Public Administration Office which has a considerable staff strength of 69 (out of the total 183 employees in this group). The other employer in this sector which indicated that they are prepared to relocate is likely to be a Government funded healthcare facility which does not need to be located in the CBD.

Of those companies that indicated a possible relocation, the questionnaire option of “a non-CBD location within Metropolitan Melbourne” was the unanimous choice. Additional comments and feedback provided by some of the participants suggest that the fringe of the CBD is the most likely alternative location.

C5. Conclusion

The main aim of this report is to detail the survey design, implementation and results of the Melbourne CBD employer survey which was conducted as part of this PhD research. Analyses of the results are not included in this report and are presented in the main thesis.

The objective of the survey was to gather information from the CBD employers regarding the potential impact that rail congestion may have on their business costs. The survey findings would be used as inputs in the next stage of research involving CGE modelling to estimate the economic impact to Melbourne CBD.

In compliance with the ethical requirements of SCERH, ethical approval was sought and granted (approval number 2009000622) in May 2009. Thereafter, the pilot survey was undertaken between 25thMay and 26th Jun 2009. The main survey commenced on 10th August 2009 and finished on 30th September 2009.

About 250 emails and 600 telephone calls were undertaken in the main survey. A total of 65 companies which employ some 1,110 employees participated in the survey. This achieved a reasonable sample size of about 0.6%. Based on the number of telephone calls made, the result yielded a final opt-in rate to the survey of about 11%.

Observations and feedback from the survey suggested that survey fatigue and the poor economic climate as primary reasons for the low participation rate of the survey. The survey response also indicated that larger establishments showed less interest than small and medium size firms in participating in surveys. This is because larger firms are less concern about the rising congestion level since they have better facilities to retain / attract staff and their employees are largely made up of professionals who have lower employment mobility. In addition, these firms are also less willing to shift out of the CBD as their client market is largely based in the CBD.

Overall, the survey responses suggested that a 10% rail capacity constraint may be associated with a 2.09% increase in CBD remuneration and a 0.97% drop in CBD employment in the short term. On the other hand, a 30% rail capacity constraint may be associated with a 3.75% increase in CBD remuneration and a 1.86% reduction in the CBD's employment in the short term.

Attachment 1 – Survey Questionnaire

Melbourne CBD Employer Survey (Productivity Impact)

1. Introduction and general instructions

Thank you for agreeing to participate in this survey.

My name is Evan Gwee and I am conducting a research project with Professor Graham Currie from the Institute of Transport Studies in the Department of Civil Engineering towards a PhD at Monash University. This means that I will be writing a thesis which is the equivalent of a 300 page book.

The aim of my research is to expand the conventional Cost-Benefit Analysis (CBA) framework for the appraisal of urban passenger rail projects by improving the methodologies for estimating the benefits of urban passenger rail projects. The findings of this research project may contribute to the economic assessment of future rail investment projects in Victoria as well as other States in Australia.

This survey titled "Melbourne CBD Employer Survey" which is an integral part of my research project is designed to collect feedback regarding the impact of transport congestion on the productivity of businesses in the CBD. This survey questionnaire contains 18 questions which are structured as follows:
Part (A) – Profile of your Company and employees,
Part (B) – Future employment plans of your Company; and
Part (C) - Potential Impact to your Company's business.

Confidentiality
Your data will be anonymous; no identifying information will be associated with your responses. Storage of the data collected will adhere to Monash University regulations and will be kept on University premises in a locked cupboard / filing cabinet for 5 years. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. A summary of the results of this survey will be made available on request; if you would like to be informed of the aggregate research finding, please contact the Student Researcher Evan Gwee at the address below. The findings from this survey are expected to be accessible from December 2009.

For any queries or clarification on the survey questions, please contact Evan Gwee at:

Email – Evan.Gwee@eng.monash.edu.au or
Telephone – 9905 8901 (office – Mon to Fri, 9am to 5pm) or 0413 855 282 (mobile).

Page 1

Melbourne CBD Employer Survey (Productivity Impact)

2. Part A - Profile of your Company

This section of the survey is intended to gather information about your company as well as the composition and travel behaviour of your employees for this specific address within Melbourne CBD.

* 1. Which industry is your company in? (please select the most appropriate one from the following list)

- ☐ Finance and Insurance
- ☐ Business and Management Services
- ☐ Hotel and Food Services
- ☐ Retail and Wholesale
- ☐ Public Administration & Safety, Education & Training, Healthcare & Social assistance
- ☐ Information media and telecommunication services
- ☐ Administrative & Support, Hiring & Rental, Arts and Recreational services
- ☐ Other (please specify – e.g. Construction, Agriculture and Mining) _____

2. How many years has your company been located at this address within Melbourne CBD?

_____

* 3. What is the current total number of staff at this address?

Number of full-time employees	
Number of part-time employees	
Number of temporary and contract workers	
Total staff at this location	

* 4. Please indicate the occupation type of your company's employment at this address.

Number of Manager and Professional staff	
Number of Clerical and Administrative staff	
Number of Service staff and Technicians	
Number of Labourers, Machine Operators & Drivers	
Other	
Total (note: this should match the total given in Question 3)	

Melbourne CBD Employer Survey (Productivity Impact)

5. How do your employees at this address travel to work?

Percentage by car (including taxi)

Percentage by public transport

Percentage by cycling and walking

Percentage by other modes

6. Please indicate what your response given in Question 5 is based on.

- [ ] Rough estimation
- [ ] Staff survey
- [ ] Other

please specify (e.g. Office records)

Melbourne CBD Employer Survey (Productivity Impact)

3. Part B – Future Employment Plans of your Company

This section of the survey is intended to gather inputs about your company's future employment plans for this address in the CBD.

7. Please estimate how the total number of employees in your company at this address has changed over the last few years?

Last 2 years (% change in employment from 2007 to 2009)

Last 5 years (% change in employment from 2004 to 2009)

8. Thinking back to this time last year, how much did you anticipate the employment to change at this address for the next few years?

Over 2 years (i.e. % change in employment from 2008 to 2010)

Over 5 years (i.e. % change in employment from 2008 to 2013)

9. Please indicate the percentage change in the employment of your company at this address over the past 1 year since the current economic downturn started (i.e. from 2008 to 2009).

10. Based on the current economic situation, how much would you expect the total number of employees in your company at this address to change in the next few years?

Over 2 years (i.e. % change in employment from 2009 to 2011)

Over 5 years (i.e. % change in employment from 2009 to 2014)

Melbourne CBD Employer Survey (Productivity Impact)

4. Part C - Potential Impact to your Company's Business

Please consider the following hypothetical scenarios.

Congestion on the CBD's road and train system during the AM peak is expected to increase in the future. Our research has conducted a series of transport scenario testing to examine how the CBD's accessibility will be affected by the increase in rail congestion. The results suggest that by year 2011, the train system will be more overcrowded and more rail users will switch to use the car instead; this will increase the travel time by car to the CBD in the AM peak. Overall travel to the CBD is going to become more difficult and less pleasant. Two possible scenarios for travel time by car in the AM peak in 2011 due to increasing rail congestion are outlined below.

Scenario A - travel time by car to the CBD will increase on average by about 15% (or 1-10 minutes depending on distance travelled); and

Scenario B - travel time by car to the CBD will increase on average by about 25% (or 5-15 minutes depending on distance travelled).

11. If the above scenarios were to occur, what incentives would your company offer to keep existing employees or to attract new employees?

- [ ] Free car parking for carpool
- [ ] Free company transport
- [ ] Flexible working hours
- [ ] Work from home
- [ ] None of these

12. If the above scenarios were to occur, do you think your company would have to increase employee remuneration to keep existing employees or to attract new employees?

- [ ] Yes - please proceed to Question 13
- [ ] No - please proceed to Question 14

13. Can you provide a broad estimate of how much you think salaries or other remuneration might have to be increased to compensate employees at this location for commuting difficulties under the two congestion scenarios for the future?

Scenario A (% change in remuneration from 2009 to 2011) _____

Scenario B (% change in remuneration from 2009 to 2011) _____

14. If the above scenarios were to occur, do you think this will affect your future plans to change the number of employees you have at the present address in the next few years?

- [ ] Yes - please proceed to Question 15
- [ ] No - please proceed to Question 16

Melbourne CBD Employer Survey (Productivity Impact)

15. If the above scenarios were to occur, how would you change your future employment estimate at this address for Year 2011?

Scenario A (% change in employment from 2009 to 2011)

Scenario B (% change in employment from 2009 to 2011)

16. If the above scenarios were to occur, would your company consider relocating out of the CBD in the longer term?

- [ ] Yes - please proceed to Question 17
- [ ] No - please proceed to Question 18

17. Which of the following would be the most likely alternative relocation option for your company?

- [ ] Relocate to another non-CBD location within Metropolitan Melbourne.
- [ ] Relocate to another Victorian location outside Metropolitan Melbourne.
- [ ] Relocate to another Australian State.
- [ ] Move out of Australia.

18. Additional comments - Please add any additional comments as you wish.

Melbourne CBD Employer Survey (Productivity Impact)

5. End of Survey

This brings you to the end of our survey. Thank you very much for taking the time to participate in our survey.

If you would like to contact the researchers about any aspect of this study, please contact the Chief Investigator:

Professor Graham Currie
Building 60 Monash University
Clayton Victoria 3800
Australia
Tel: +61 3 9905 5574
Fax: +61 3 9905 4944
Email: graham.currie@eng.monash.edu.au

If you have a feedback concerning the manner in which this research is being conducted, please contact:

Executive Officer, Human Research Ethics
Standing Committee on Ethics in Research Involving Humans (SCERH)
Building 3e Room 111
Research Office
Monash University VIC 3800

Tel: +61 3 9905 2052
Fax: +61 3 9905 1420
Email: scerh@adm.monash.edu.au

Note: Please cite this project's number – CF09/1217-2009000622 in correspondence.

Appendix D

Secondary Data Analysis

This appendix presents the detailed calculations of the secondary data analysis reported in Section 7.3. For explanation purposes, an example of the calculation based on Melbourne metropolitan area is included in this appendix. The approach comprises the following 2 steps.

Step 1: Estimation of CBD employment Size, Concentration and GRP

This step estimates the employment size and Gross Regional Product (GRP) of each city's Central Business District (CBD) using data on the job density, the proportion of jobs within the CBD and the metropolitan GRP per capita[1] from UITP (2001). The employment size and GRP of each CBD are estimated using Equation D.1 and D.2 respectively. Equation D.3 estimates the employment concentration (i.e. the number of workers per unit area) of the CBD.

$$\text{CBD employment size} = \left(\frac{\text{Metropolitan Population}}{\text{Population density}}\right) * \text{job density} * \text{proportion of jobs in CBD} \quad \text{(Equation D1)}$$

$$\text{CBD GRP} = \text{CBD employment size} * \left(\frac{\text{Metropolitan GDP per capita} * \text{Metropolitan Population}}{\text{Metropolitan Employment}}\right) \quad \text{(Equation D2)}$$

$$\text{CBD employment concentration} = \text{CBD employment size} / \text{CBD area} \quad \text{(Equation D3)}$$

Example – Melbourne CBD (part 1)

The following will explain these 3 equations further using Melbourne City as an example.

[1] UITP (2001) term this as the metropolitan Gross Domestic Product (GDP) per capita.

According to UITP (2001), the 1995 data for Melbourne city were as follows:

- Total population – 3.14 million people
- Population density – 13.68 people / ha
- Employment density – 5.68 workers/ ha
- Proportion of jobs in the CBD – 9.44%
- Metropolitan GRP per capita – US$21,475.54.

With reference to Equation D1, the total employment in Melbourne CBD was estimated as follows:

CBD employment size = (3.14 million people / 13.68)* 5.68*9.44%
= 123,000 workers.

Based on the above calculation, the total employment of Melbourne city is essentially = (3.14 million people / 13.68)* 5.68 = 1.30 million workers.

The GRP contribution per worker in Melbourne city was first estimated using the data on the metropolitan GRP per capita, total population and employment of Melbourne city. The total employment of Melbourne city was estimated as follows:

Melbourne City's GRP contribution per worker
= ($21,475.54* 3.14million people) / 1.30 million workers
= $51,871.69.

Using equation D2, the total GRP for Melbourne CBD is therefore
= 123,000 workers*$51,871.69 contribution per worker
= $6.36 billion.

Information from Kenworthy and Laube (1999a) indicated that the area of Melbourne CBD is about 3.50km^2. Using Equation D3, the CBD employment concentration for Melbourne CBD = 123,000 workers / 3.50km^2
= 35,142 workers / km^2.

The above calculations using the corresponding data from UITP (2001) and Kenworthy and Laube (1999a) were repeated for the other 19 international cities to estimate their CBD employment size, employment concentration and GRP.

Step 2: Estimation of daily rail capacity provision serving the CBD

In step 2, the daily rail capacity provided to serve each metropolitan area was first estimated as follows:

Step (2a and b) - Estimation of total carrying capacity per rail car

a. The average seating capacity per rail car was derived based on the total rail car seat-km per capita and the rail car-km per capita (from UITP (2001)) as per Equation D4.

b. The total carrying capacity per rail car was then estimated by factoring the average seating capacity (from step a) with a standing / seating ratio – see Equation D5. The standing / seating ratio was assessed using the rolling stock information from the respective rail operators and transport agencies.

$$\textit{Average seating capacity / rail car} = \left(\frac{\textit{Total rail car seat-km per capita}}{\textit{Rail car-km per capita}} \right) \qquad \text{(Equation D4)}$$

$$\textit{Total carrying capacity / rail car} = (\textit{Average seating capacity / rail car}) * \left[1 + \left(\frac{\textit{Standing capacity}}{\textit{Sitting capacity}}\right)\right] \qquad \text{(Equation D5)}$$

Step (2c – 2e) - Estimation of total number of rail car vehicle trips per day

c. The product of the rail car-km per capita and the residential population of each city (from UITP (2001)) yields the annual rail car-km travelled in each city (Equation D6).

d. The output from step (c) was divided with the working day annualisation factor to compute the daily rail car-km travelled in each city (Equation D7) – Connex Melbourne (2009) recommended an annualisation factor of 295 for Melbourne; this value was adopted for the other cities.

e. The total number of rail car trips made per day was then calculated by dividing the daily rail car-km travelled (from step (d)) with the average rail trip length using Equation 7.8. The average rail trip length was derived based on the total rail network rail route length and total number of rail lines information from the respective rail operators. This is represented in Equation D8.

*Annual rail car-km travelled = rail car-km per capita * metropolitan population*

(Equation D6)

$$\textit{Daily rail car-km travelled} = \frac{\textit{Annual rail car-km travelled}}{\textit{Annualisation Factor}} \qquad \text{(Equation D7)}$$

$$\textit{Total rail car trips per day} = \frac{\textit{Daily rail car-km travelled}}{\textit{Average rail trip length}} \qquad \text{(Equation D8)}$$

The product of the total carrying capacity per rail car (from step b) and the total number of rail car trips per day (from step e) would yield the daily rail capacity provided to serve each city (Equation D9).

An assessment based on the rail network configuration was made to estimate the proportion of the daily rail capacity serving each city that enters the CBD. For most cities where the rail lines run radially from the CBD, this thesis assumes that 50% of the city's daily rail services enter the CBD – the other 50% are leaving the CBD. For the remaining few cities (such as London and Toronto) whose rail network include non-radial lines, the proportion of the daily rail capacity serving the CBD was estimated based on the amount of radial and non-radial services according to their rail service timetables. Equation D10 estimates the daily rail capacity provided to serve each CBD.

Daily rail capacity provided to serve each city
*= total carrying capacity per rail car * total number of rail car trips*

(Equation D9)

Daily rail capacity provided to serve each CBD
*= Daily rail capacity provided to serve each city * proportion of city rail network that serves CBD* (Equation D10)

Example – Melbourne CBD (part 2)

The following will explain step 2 further using Melbourne City as an example.

According to UITP (2001), the 1995 data for Melbourne city were as follows:

- Total rail car seat-km per capita – 1911.96
- Rail km per capita – 20.55.

Based on Equation D4, the average seating capacity per rail car for Melbourne
= 1911.96 / 20.55
= 93 seats.

According to DOT (2008b), the maximum carrying capacity (sitting plus standing capacity) per train in Melbourne is about 798 passengers. On average, a train operating in Melbourne city comprises of 6 rail cars. This means that each rail car has a maximum carrying capacity of 133 passengers.

Connex Melbourne (2009) indicated that a total of 93 seats are provided in each rail car – this is confirmed via site observations. Based on these figures, the total standing capacity of each rail car is therefore 40 (=133 – 93) passengers. Therefore, the standing / seating ratio = 40 / 93 = 0.43.

Using Equation D5, the total carrying capacity per rail car for Melbourne
= 93*(1+0.43)
= 133 passengers.

It may appear redundant to estimate the total carrying capacity per rail car using the approach shown above. However, as the rolling stock information for most cities only indicate the standing and seating capacity per rail car (rather than the carrying capacity per train as in the case for Melbourne city), the above-mentioned approach is necessary to estimate the carrying capacity per rail car.

Using Equation D6, the annual rail car-km travelled for Melbourne City
= 20.55 * 3.14 million
= 64.49 million rail car-km

Using an annualisation factor of 295 as advised by Connex Melbourne (2009) and Equation D7, the daily rail car-km travelled in Melbourne city
= 64.53 million rail car-km / 295
= 0.22 million rail car-km
The annualisation factor of 295 was adopted for the other cities in the absence of information.

As indicated in Section 4.3.1, the Melbourne metropolitan train network includes 15 rail lines that spans 370km in total route length. That gives an average trip length of about 24.6km (=370/15).

Using Equation D8, the total rail car trips serving Melbourne city per day
= 0.22 million rail car-km / 24.6km
= 8,815 rail car trips.

It was earlier estimated that each rail car can carry a total of 133 passengers. Therefore, using Equation D9, the total rail carrying capacity provided to serve Melbourne city is
= 8,815 rail car trips * 133 passengers per rail car
= 1.17 million passenger trips.

Given that the rail lines run radially from Melbourne CBD and the train timetables suggest that almost all the rail lines that run through the metropolitan network enters Melbourne CBD, this thesis assumes that 50% of the daily rail capacity provided to serve Melbourne city enters the CBD – the other 50% are leaving the CBD. Based on this assumption, Equation D10 shows that the total daily rail capacity provided to serve Melbourne CBD was estimated to be
= 0.59 million passenger trips (=50%*1.17 million).

The above calculations using the corresponding data from UITP (2001) and rolling stock information from the relevant rail operators were repeated for the other 19 international cities to estimate their daily rail capacity provision to serve their CBD. For those cities were the rail network includes some lines that do not run radially from the CBD, an estimation is made from the train time tables (if available) or from the network coverage (based on length or number of stations) of the proportion of the train capacity that is provided to serve the CBD. An example based on the Toronto network is provided next. Details of the 20 cities are summarised in Table D1.

Example – Toronto City

The following section of this appendix will explain the details of how the proportion of the daily rail capacity serving the CBD was estimated for city's whose rail network included both radial and non-radial lines. The rail network for Toronto (shown in Figure D1) is used as an example for illustration.

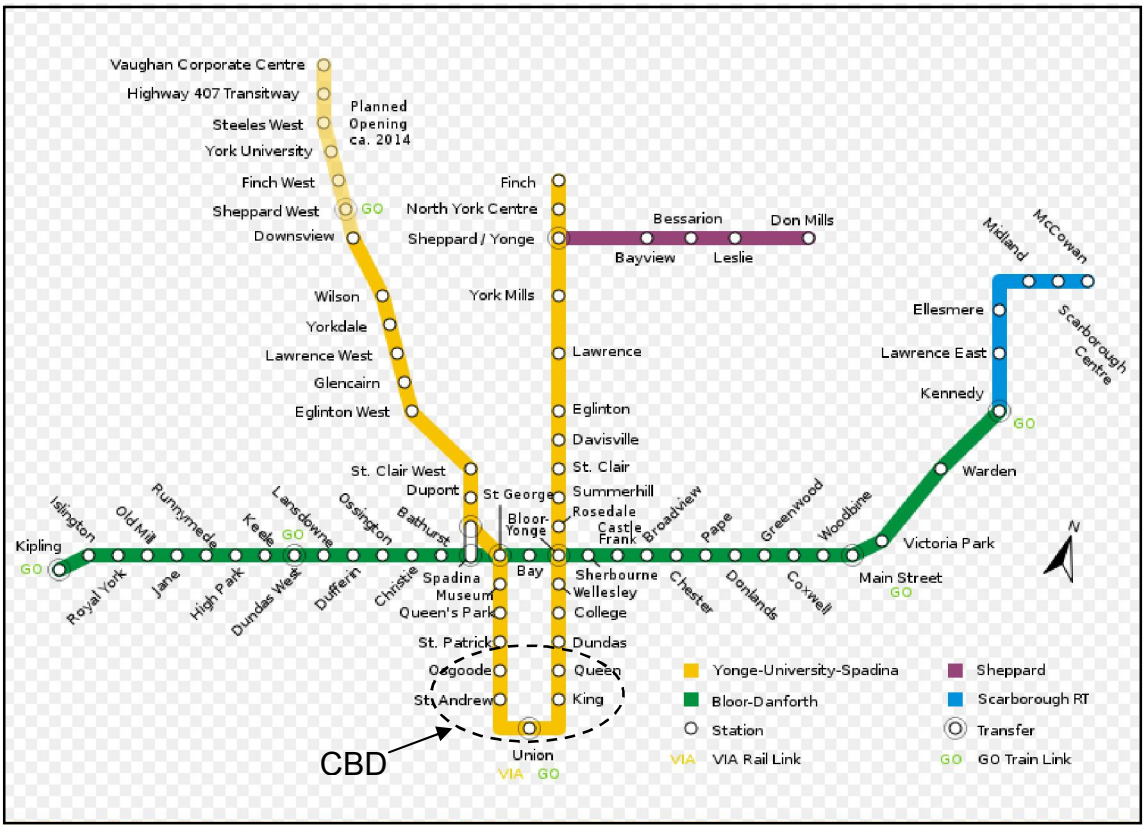


Figure D1: Rail network serving City of Toronto

According to GHK International (Canada) Ltd (2000, page 6), the CBD of Toronto City is being served by the following 5 train stations:

1. Queen station
2. King station
3. Union station
4. St Andrew station
5. Osgoode station.

Toronto Transit Commission (2010) does not provide detailed schedule for each subway line since it is not practical to do given that most the rail lines[2] runs at a frequency of 2-3 minutes during the peak hours and 4-5 minutes during the off-peak. Considering the CBD as a major destination point, it appears from the rail network that there are 2 rail lines that run radially into the CBD – i.e. the 2 legs of the Yongge-University-Spadina Line – and one line that runs non-radially – i.e. the Bloor-Danforth Line. Therefore, it would be reasonable to estimate that at least two-thirds (or 67%) of the daily rail capacity is provided to serve the CBD. The thesis raised this proportion slightly to 70% to take into consideration that the Scarborough RT Line has a lower frequency and is an extension of the non-radial Bloor-Danforth Line. Again assuming that half of the services enters the CBD, the assessment estimated that 35% (=70% * 50%) of the daily rail capacity provided to serve Toronto City enters its CBD.

[2] Except the Scarborough RT Line which operates at a frequency of 4-5 minutes during the peak and 5-6 minutes during the off-peak.

Table D1: Details of the 20 cities

No.	1	2	3	4	5	6	7	8	9	10
City	**Melbourne**	**Brisbane**	**Perth**	**Sydney**	**Brussels**	**Copenhagen**	**Dusseldorf**	**Frankfurt**	**Helsinki**	**Hong Kong**
Total population	3,138,147	1,488,883	1,244,320	3,741,290	948,122	1,739,458	571,064	653,241	891,056	6,311,000
pop density (people / ha)	13.68	9.59	10.90	18.93	72.39	28.49	49.23	47.64	33.00	320.36
job density (workers / ha)	5.68	4.00	4.57	8.04	47.58	14.95	35.23	38.70	16.15	151.28
Total employment in metro area ('00,000)	13.03	6.21	5.22	15.89	6.23	9.13	4.09	5.31	4.36	29.80
% of employees working in CBD	9.44%	11.92%	19.15%	12.80%	26.68%	14.14%	34.26%	20.46%	21.33%	6.35%
Total CBD employment ('00,000)	1.23	0.74	1.00	2.03	1.66	1.29	1.40	1.09	0.93	1.89
CBD area (km^2)	3.50	2.50	7.50	4.20	3.11	4.67	4.20	2.33	2.50	1.10
CBD employment concentration ('00,000 workers / km^2)	0.35	0.30	0.13	0.48	0.53	0.28	0.33	0.47	0.37	1.72
Metropolitan GDP per capita (95 US$)	$21,475.54	$15,036.29	$21,995.20	$22,397.32	$28,008.58	$37,058.29	$43,744.89	$54,570.75	$28,323.35	$22,968.45
Total GDP for metro area ($billion)	$67.39	$22.56	$27.58	$84.45	$23.53	$42.37	$22.17	$31.63	$20.87	$149.55
GDP contribution per worker ($)	$51,722.78	$36,332.75	$52,873.39	$53,148.33	$37,758.63	$46,418.32	$54,243.60	$59,610.76	$47,848.86	$50,182.92
CBD GRP (billion)	$6.36	$2.69	$5.28	$10.81	$6.28	$5.99	$7.59	$6.47	$4.45	$9.50
Total rail car seat-km per capita	1,911.96	2,768.05	761.22	4,872.62	2,598.20	3,468.51	1,167.58	1,945.29	1,431.34	1,213.36
Rail car-km per capita	20.55	33.81	10.05	44.2	36.53	54.73	14.59	35.23	18.29	24.32
total no. of seats provided per rail car	93	82	76	110	71	63	80	55	78	50
Total capacity / seating ratio	1.43	1.5	2.2	1.35	1.43	3	1.35	2.5	3	6
Total carrying capacity per rail car	133	123	167	149	102	190	108	138	235	299
Annual rail car-km travelled (million rail car-km)	64.49	50.34	12.51	165.37	34.63	95.20	8.33	23.01	16.30	153.48
Daily rail car-km travelled (million rail car-km)	0.22	0.17	0.04	0.56	0.12	0.32	0.03	0.08	0.06	0.52
total route length (km)	372	344	173.1	520	43.7	155	139.4	58.6	21.1	175
no. of lines	15	12	6	16	6	7	7	7	2	10
average trip length (km)	24.80	28.67	28.85	32.50	7.28	22.14	19.91	8.37	10.55	17.50
Total no. of car trips per day provided to serve city	8,815	5,953	1,469	17,248	16,120	14,574	1,418	9,319	5,237	29,730
Total carry capacity provided per day (mil pax trips)	1.17	0.73	0.24	2.57	1.64	2.77	0.15	1.29	1.23	8.90
Proportion going into CBD per day	50%	50%	50%	50%	40%	50%	50%	50%	50%	50%
Daily rail provision in direction of CBD ('00,000)	5.86	3.65	1.22	12.83	6.37	13.86	0.77	6.43	6.15	44.50

Table D1: Details of the 20 cities (con't)

No.	11	12	13	14	15	16	17	18	19	20
City	**London**	**Munich**	**NY**	**Paris**	**S'pore**	**Stockholm**	**Tokyo**	**Toronto**	**Vancouver**	**Vienna**
Total population	7,007,100	1,324,208	19,227,361	11,004,254	2,986,500	1,725,756	32,342,698	4,628,883	1,898,687	1,592,596
pop density (people / ha)	59.07	55.66	18.04	47.62	93.53	29.03	87.68	25.53	21.61	69.39
job density (workers / ha)	31.50	32.31	9.49	21.31	53.23	14.11	47.53	12.80	10.44	37.08
Total employment in metro area ('00,000)	37.37	7.69	101.15	49.24	17.00	8.39	175.32	23.21	9.17	8.51
% of employees working in CBD	28.04%	36.29%	20.72%	18.07%	16.38%	13.33%	14.26%	6.45%	12.57%	11.79%
Total CBD employment ('00,000)	10.48	2.79	20.96	8.90	2.78	1.12	25.00	1.50	1.15	1.00
CBD area (km^2)	29.78	8.03	23.04	29.00	7.00	4.14	42.20	1.81	3.36	2.85
CBD employment concentration ('00,000 workers / km^2)	0.35	0.35	0.91	0.31	0.40	0.27	0.59	0.83	0.34	0.35
Metropolitan GDP per capita (95 US$)	$22,362.90	$54,692.08	$34,395.30	$41,304.98	$28,577.93	$33,437.69	$45,424.89	$19,455.68	$25,793.02	$39,316.43
Total GDP for metro area ($billion)	$158.47	$64.27	$646.46	$430.61	$64.39	$41.75	$1,469.16	$99.75	$54.24	$57.80
GDP contribution per worker ($)	$42,409.23	$83,605.46	$63,913.67	$87,443.45	$37,884.34	$49,769.66	$83,796.64	$42,979.62	$59,133.26	$67,915.54
CBD GRP (billion)	$44.43	$23.32	$133.95	$77.81	$10.55	$5.56	$209.50	$6.43	$6.82	$6.81
Total rail car seat-km per capita	5,608.68	3,763.08	2,116.02	2,307.87	1,142.47	4,623.48	4,432.65	1,378.59	505.50	2,072.20
Rail car-km per capita	93.91	65.32	37.73	50.33	18.43	73.59	79.8	17.24	13	37.4
total no. of seats provided per rail car	60	58	56	46	62	63	56	80	39	55
Total capacity / seating ratio	4	4	5	5	7	3	7	3	3	2.5
Total carrying capacity per rail car	239	230	280	229	434	188	389	240	117	139
Annual rail car-km travelled (million rail car-km)	658.04	86.50	725.45	553.84	55.04	127.00	2580.95	79.80	24.68	59.56
Daily rail car-km travelled (million rail car-km)	2.23	0.29	2.46	1.88	0.19	0.43	8.75	0.27	0.08	0.20
total route length (km)	400	221	369	214	118.9	100	328.8	68.3	68.7	69.8
no. of lines	11	10	24	16	4	3	13	4	3	6
average trip length (km)	36.36	22.10	15.38	13.38	29.73	33.33	25.29	17.08	22.90	11.63
Total no. of car trips per day provided to serve city	61,342	13,267	159,945	140,369	6,277	12,915	345,914	15,843	3,654	17,356
Total carry capacity provided per day (mil pax trips)	14.65	3.06	44.85	32.18	2.72	2.43	134.50	3.80	0.43	2.40
Proportion going into CBD per day	35%	50%	35%	50%	50%	50%	50%	35%	50%	50%
Daily rail provision in direction of CBD ('00,000)	51.30	15.29	156.93	160.85	13.62	12.17	672.51	13.30	2.13	12.02

Appendix E

Theoretical Structure of TERM

Given the size of the TERM model, it is not practical to provide a full description of TERM's theoretical structure in this appendix. Hence, this appendix only presents the core equations of the TERM model. The detailed documentation of TERM's structure can be found in Horridge et al. (2003) and Wittwer and Horridge (2010).

Table E1 shows the core equations of TERM presented in TABLO[1] form – this table is heavily dependent on Wittwer and Horridge (2010). Tables E2 and E3 describe the variables and the model's sets and set elements. The 51 sets of equations and 72 variables presented in Tables E1 and E2 summarise the structure and functioning of the 191 equations and 175 sets of variables of the TERM model used in this thesis. The 51 core equations as they relate to TERM's theoretical structure are explained next.

1. Sourcing mechanism in TERM

One of the defining features in TERM is its regional sourcing mechanism. In TERM, economic agents decide on the geographical source of their purchases based on relative prices and a nested structure of substitution possibilities. The first decision facing the economic agent is whether to purchase a commodity that is produced in Australia or one that is imported from overseas. If an Australian product is chosen, a second decision must be made as to the particular region the commodity originates from.

[1] TABLO language is a syntax that is very similar to ordinary algebra (see Section 8.2.3 for more details). The core equations shown in Table 8.1 are based on Witter and Horridge (2010) but presented in a TABLO form to facilitate the reading of this section.

Equations E1 to E4 define this two stage sourcing mechanism in TERM. Equations E1 and E2 indicate that users – which include industries, households, investors, exporters and government - of commodities minimise their costs subject to Constant Elasticity of Substitution (CES)[2] between domestic composite and imports; Equations E3 and E4 define the substitution possibilities between sub-national sources to form the domestic composite and to determine the regional ports-of-entry of imported commodities. Within the CES nest, changes in relative prices would invoke substitution towards the relatively cheaper inputs. As can be seen from Equation E3, the equations governing the demands by regional source contain no user subscript since TERM assumes that all users in a particular region of a particular commodity source their purchases of that commodity from regions according to common proportions.

2. Industry demands and supply

Equations E5 - E13 define the cost minimising behaviour in primary factor and intermediate goods demands by industry users. Firms are subjected to a nested production function that allows substitution between primary factors (land, labour and capital), and between sources of supply of intermediate inputs based on a CES specification (Horridge, 2003). The "Armington assumption"[3] is adopted in the sourcing of intermediate inputs. Each regional industry produces a single commodity, which is an imperfect substitute for the same commodity produced in other regions or imported from overseas; again within the CES nest, changes in relative prices would invoke substitution towards the relatively cheaper inputs.

Industry users minimise their costs for labour subject to a CES substitutability across occupation mix *o* as shown in Equations E5 and E6. Occupation-specific labour demands are L_{id}^{o} and labour composite demands $L1_{id}$, with corresponding wages being W_{id}^{o} and $W1_{id}$. Equation E7 to E10 specify primary demands for labour composite $L1_{id}$, capital K_{id} and land LND_{id} subject to a composite factor demand $XPRIM_{id}$ by industry *i* in region *d*. Equation E11 relates $XPRIM_{id}$ to the total industry output, $XTOT_{id}$ via a primary factor augmenting factor, $APRIM_{id}$.

[2] CES stands for Constant Elasticity of Substitution (Dixon et al., 1982). As the name suggests, CES function exhibits constant elasticity of substitution between capital and labour (Johansen, 1972, page 178).

[3] Armington assumes that imports are imperfect substitutes for domestic supplies (Dixon et al., 1982, page 69).

Equations E12 and E13 define the industry users' demands for intermediate goods which is related to output $XTOT_{id}$. The supply of domestically-produced commodities is determined based on the assumption that producers earn zero pure profits and adjust their output to where the price they receive equals marginal cost. This is represented by Equation E14. Equations E15 and E16 introduce production taxes to industry costs.

TERM allows the modelling of industries which have multi-product capabilities. For such industries, their supplies of commodity *c* by industry *i* in region *d* $XMAKE_{cid}$ is subjected to a CET[4] relationship between the industry output prices and the average commodity price $PDOM_{cd}$. These are specified by Equations E17 and E18. TERM assumes that the supply of imports is infinitely elastic. Therefore, as specified by Equation E19, the price of imports $PIMP_{cd}$ is defined by the product of the foreign import prices $PFIMP_{cd}$ and the nominal exchange rate Φ.

3. Household demands and supply

Similar to other ORANI-style models, in TERM, household demands follow a linear expenditure system[5] in each region (Dixon et al., 1982 page 101). Regional households maximise a Klein-Rubin[6] utility function by choosing among effective units of commodity *i* (which are in turn a cost-minimising CES combination of *i* from the various regions and sources), subject to an aggregate expenditure constraint $W3TOT_d$. Households will substitute between goods and between geographical sources of those goods depending on their price (Dixon et al., 1982 page 102). This gives rise to the household demand equations represented by Equations E20 to E23.

[4] CET stands for Constant Elasticity of Transformation. According to Horridge (2003, page 25), the CET function is identical to the CES function except that the transformation parameter in the CET has the opposite sign to the substitution parameter in the CES function; that means an increase in the relative price of a commodity would induce a transformation in favour of that output.

[5] A linear expenditure system is one where the expenditure on any commodity is a fixed proportion of total expenditure (Stone, 1954).

[6] Klein-Rubin utility function is a non-homothetic utility whereby a rising income causes budget shares spent on different goods and services to change even though the price ratios are fixed (Horridge, 2003, page 28).

4. Investment demands

Similar to other ORANI-style models, TERM treats investors as allocating their funds between industries in order to maximise their rate of return (Horridge et al., 2003). In assembling units of capital in each industry, it is generally assumed in ORANI that each individual industry has a particular commodity-input pattern to capital creation and that industries choose inputs from different sources in order to minimise the cost of creating a unit of capital (Horridge et al., 2003). This gives rise to the capital formation input demand equation represented by Equation E24.

These equations are derived from an assumption of cost minimisation on the part of regional industries in the production of their own capital. Capital creation is subjected to a two-tier production function in which effective units of commodities are first formed as a CES combination of source-specific commodities; these are then being put together to a Leontief production function[7].

Equation E26 computes an industry investment index $PI2_{cd}$ which is in turn used to define the gross rate of return $GRET_{cd}$ in Equation E28. Equation E29 specifies the investment-to-capital ratio $GGRO_{cd}$. According to Wittwer and Horridge (2010), in typical short run simulations, capital stocks K_{id} are exogenous with gross rate of return endogenous - the converse in long run simulations. This is to fix the capital stock in the short run and the reverse in the long run. Equation E30 follows ORANI investment rule (Dixon et al., 1982, page 118 - 122). Wittwer and Horridge (2010) highlighted that the investment slack variable $Invslack$ is exogenous except when the simulation involves a macro investment target.

[7] A Leontief production function is a special case of CES; it is a specification where the factors of production will be used in fixed proportions and there is no substitutability between factors (Dixon et al.1992, page 142).

5. Government demands

Equation E31 defines current consumption demands by regional governments. TERM assumes that government demands are independent of prices and proportional to three corresponding shifters[8] which shift government demands with different dimensions: by *d* as $FGOVTOT_d$, by *c* and *d*, as $FGOV_S_{cd}$, and by *c,s* and *d*, as $FGOV_{csd}$.

6. Export demands

Equation E32 - E35 define foreign demands for commodities from each region. Export demands are simulated using a two-stage process. First, regional source-specific exports $X4_{cd}$ form a CES composite. National exports are then linked to international demands as specified in Equation E35. A downward sloping export demand curve for each commodity captures the level of existing demand and the responsiveness of foreigners to changes in Australian supply prices i.e. the export volumes are inversely related to foreign currency export prices via constant elasticity export demand function γ . Equation E36 defines inventory demands. Inventories XST_{id} are proportional to industrial outputs $XTOT_{id}$ multiplied by a shifter FST_{id} .

7. Margins

As highlighted earlier, the valuation of the flow of commodities and primary factors is a key feature of the regional sourcing mechanism in TERM. In order for goods to reach a customer located in a particular region, certain margins services (e.g. transport, wholesale and retail trade) must also be purchased. It is assumed in TERM that the purchasers of a particular commodity substitute the product from various origins based on the change in the relative price of margins sourced from different localities, particularly with regard to transport. Equation E37 defines the demands for margins $XTRADMAR_{rd}^{csm}$ which is proportional to the demands for commodity XT_{rd}^{cs} subject to a margins-using technology, $ATRADMAR_{rd}^{csm}$.

[8] A shifter is a variable that can be used to model a movement in the flow level of specific goods and services for specified economic agents (Dixon et al., 1982, page 22). For instance, if there is an upward movement in the demand of the government in region d, this can be modelled by increasing $FGOVTOT_d$. The choice of which shift variables are exogenous also determines at run time which sets of equations are operative in the rest of the model (Horridge, 2003, page 33) – see Section 8.3.2.5 for more information.

According to Horridge et al. (2005), the flow of commodities and primary factors are valued according to 3 methods:

1. Basic values = output prices (for domestically-produced goods), or CIF[9] prices (for imported goods),
2. Delivered values = Basic + Margins; and
3. Purchasers' values = Basic + Margins + Tax = Delivered + Tax

Equation E38 specifies that the delivered price PD_{rd}^{cs} is the sum of the basic commodity price $PBAS_{r}^{cs}$ and margins' prices PM_{rd}^{m}. Equation 8.40 relates the user or delivered price (PU_{d}^{cs}) of commodities to the purchasers' price (P_{ud}^{cs}). PU_{d}^{cs} is the margin-inclusive, tax exclusive source-composite delivered price that appears in Equations E3 and E4.

Equation E43 defines the CES substitution between regional providers *p* of margins, and to allow providers to differ from either the domestic origin or destination of the commodity being delivered. This is one of the unique features of TERM and part of its sourcing mechanism.

8. Market clearing conditions

Equations E44 - E47 define the market clearing conditions. Equation E44 specifies the market clearing conditions for industry outputs. However, additional market clearing conditions are required because of the common sourcing assumption. Equation E45 relates the sales of non-margins commodities across destinations to regional supplies while Equation E46 specifies the same for margins. Equation E47 links sales summed across users to supplies summed over regional origins.

[9] According to OECD's (2002) glossary of statistical terms, CIF price (i.e. cost, insurance and freight price) is the price of good delivered at the frontier of the importing country. The CIF price would include any insurance and freight charges incurred to that point, or the price of a service delivered to a resident, before the payment of any import duties or other taxes on imports or trade and transport margins within the country.

9. Gross Regional Product

Equation E48 and E49 calculate each region's Gross Regional Product (GRP) from the expenditure ($GRPE_d$) and income ($GRPI_d$) approach. Both sides of GRP are set equal by the above-mentioned market clearing conditions. The first 4 terms on the right-hand side of Equation E48 calculate the net expenditures of the various users (including margins) and the last 2 terms calculate the net exports. For the income approach, the first term on the right-hand side of Equation E49 calculate the gross income at factor cost while the other 2 items are indirect taxes (i.e. production and commodity tax respectively).

10. Others

Equation E50 defines the consumption function while Equation E51 sets the labour wages. In TERM, the wages are indexed to the Consumer Price Index which is represented by the term $P3_{cd}.X3_{cd}/W3TOT_d$; deviations in the growth are achieved through 3 shift variables, which allow the wages to be shifted via different dimensions: by *i, o* and *d* as $FLAB_{iod}$, by *d,* as $FLAB_IO_{cd}$, and by nationally as $FLABNAT$.

Table E1: Core equations of the TERM model

(Reproduced from Wittwer and Horridge (2010), with some modifications)

A. Cost minimisation and substitutability possibilities – sourcing mechanism in TERM
Equation E1: Quantity demand of commodity *c* from source *s* (either domestic composite or import) by user *u* in region *d* $X_{ud}^{cs} = f(X1_{ud}^{c}, CES[P_{ud}^{cs} / P1_{ud}^{c}]$
Equation E2: Average price of domestic / import composite $P1_{ud}^{c}.X1_{ud}^{c} = \sum_{s} X_{ud}^{cs}.P_{ud}^{cs}$
Equation E3: Quantity demand for all users of commodity *c* from source *s* from sub-national origin *r* to destination *d* $XT_{rd}^{cs} = f(XT1_{d}^{cs}, CES[PD_{rd}^{cs} / PU_{d}^{cs}]$
Equation E4: Average user price of sub-national source composite $PU_{d}^{cs}.XT1_{d}^{cs} = \sum_{r} XT_{rd}^{cs}.PD_{rd}^{cs}$
B. Industry demands and supply
Equation E5: Occupation *o* mix of labour demand $L_{id}^{o} = f(L1_{id}, CES[W_{id}^{o} / W1_{id}]$
Equation E6: Total wage bill $W1_{id}.L1_{id} = \sum_{o} L_{id}^{o}.W_{id}^{o}$
Equation E7: Demand for labour composite $L1_{id} = f(XPRIM_{id}, CES[W1_{id} / PPRIM_{id}]$
Equation E8: Demand for capital $K_{id} = f(XPRIM_{id}, CES[R_{id} / PPRIM_{id}]$
Equation E9: Demand for land $LND_{id} = f(XPRIM_{id}, CES[RLAND_{id} / PPRIM_{id}]$
Equation E10: Total costs for composite factor $PPRIM_{id}.XPRIM_{id} = LND_{id}.RLND_{id} + L1_{id}.W1_{id} + K_{id}.R_{id}$
Equation E11: Total Demand for composite factor $XPRIM_{id} = XTOT_{id}.APRIM_{id}$
Equation E12: Demand for intermediate goods $X1_{id}^{c} = f(XTOT_{id}, CES[P1_{id}^{c} / P11_{id}]$
Equation E13: Total costs of intermediate goods $P11_{id}.X11_{id} = \sum_{c} P_{id}^{c}.X1_{id}^{c}$

Table E1: Core equations of the TERM model (cont')

Equation E14: Zero pure profit condition $PC_{id}.XTOT_{id} = \sum_c P_{id}^c.X1_{id}^c + \sum_o W_{id}^o.L_{id}^o + R_{id}.K_{id} + RLND_{id}.LND_{id}$
Equation E15: Production tax revenue $VPTX_{id} = RPTX_{id}.PC_{id}.XTOT_{id}$
Equation E16: Industry output price $PTOT_{id}.XTOT_{id} = PC_{id}.[1 + RPTX_{id}].XTOT_{id}$
Equation E17: Supply of commodity – for industries with multi-product capability $XMAKE_{cid} = f(XTOT_{id}, CET[PDOM_{cd} / PTOT_{id}]$
Equation E18: Industry output price – for industries with multi-product capability $PTOT_{id}.XTOT_{id} = \sum_c PDOM_{cid}.XMAKE_{cid}$
Equation E19: Domestic currency import prices $PIMP_{cd} = PFIMP_{cd}.\Phi$
C. Household demands
Equation E20: Average household user prices $P3_{cd} = P1_{Hou,d}^c \qquad Hou \in User$
Equation E21: Average household demands $X3_{cd} = X1_{Hou,d}^c \qquad Hou \in User$
Equation E22: Aggregate subsistence expenditure of household $WSUB_d = \sum_c P3_{cd}.XSUB_{cd}.N_d$
Equation E23: Aggregate expenditure of household $X3_{cd} = \beta_{cd}(W3TOT_d - WSUB_d) / P3_{cd}$
D. Investment demands
Equation E24: Investment demands $X2_{id}^c = A2_{id}^c.X2TOT_{id}$
Equation E25: Investment price $P2_{cd}.X2_{cd} = P1_{Inv,d}^c.X1_{Inv,d}^c \qquad Inv \in User$
Equation E26: Price of new capital $PI2_{id}.X2TOT_{id} = \sum_c P1_{Inv,d}^c.X2_{Inv,d}^c \qquad Inv \in User$
Equation E27: Total investment costs $X2TOT_{id}.P2TOT_{id} = \sum_c P2_{cd}.X2_{id}^c$

Table E1: Core equations of the TERM model (cont')

Equation E28: Gross rate of return $GRET_{id} = R_{id} / PI2_{id}$
Equation E29: Gross growth rate of return $GGRO_{id} = X2TOT_{id} / K_{id}$
Equation E30: ORANI investment rule $GGRO_{id} = FINV1 * [(GRET_{id})^2 / Invslack]^{0.33}$
E. Government demands
Equation E31: Government demands $XGOV_{cd} = FGOVTOT_d . FGOV_{csd} . FGOV_S_{cd}$
F. Export demands
Equation E32: Export demands $X4_{cd} = f(X4NAT_c, CES[P4_{cd} . / P4NAT_c])$
Equation E33: Price of import / domestic composite for export $P4_{cd} = P1^c_{Exp,d} \qquad Exp \in User$
Equation E34: Total national export costs $P4NAT_c . X4NAT_c = \sum_d P4_{cd} . X4_{cd}$
Equation E35: Relate national exports to internationl demands $X4NAT_c = (P4NAT_c / FPEXP_c)^{-\gamma} FQEXP_c)$
G. Inventory demands
Equation E36: Inventory demands $XST_{id} = XTOT_{id} . FST_{id}$
H. Margins
Equation E37: Demand for margins $XTRADMAR^{csm}_{rd} = XT^{cs}_{rd} . ATRADMAR^{csm}_{rd}$
Equation E38: Price of delivered goods $PD^{cs}_{rd} . XT^{cs}_{rd} = PBAS^{cs}_r . XT^{cs}_{rd} + \sum_d PM^m_{rd} . XTRADMAR^{csm}_{rd}$
Equation E39: Average price of margins $PMR^m_{rd} . XMR^m_{rd} = \sum_p XMP^{pm}_{rd} . PDOM^m_r$
Equation E40: Purchasers' prices $P^{cs}_{ud} = PU^c_{sd} . T^{cs}_{ud}$

Table E1: Core equations of the TERM model (cont')

Equation E41: Basic price of domestic goods $PBAS_{d}^{c,dom} = PDOM_{cd}$
Equation E42: Basic price of imported goods $PBAS_{d}^{c,imp} = PIMP_{cd}$
Equation E43: Region sourcing of margins $XMP_{rd}^{pm} = f(XMR_{rd}^{m}, CES[PDOM_{r}^{m}./PMR_{rd}^{m}])$
I. Market clearing conditions
Equation E44: Market clearing condition for industry outputs $PTOT_{id}.XTOT_{id} + XST_{id} = \sum_{c} XMAKE_{cid}$
Equation E45: Market clearing condition for non-margins commodity sales summed across destinations to regional supplies $\sum_{d} PDOM_{rd}^{c}.XT_{rd}^{c,dom} = \sum_{i} XMAKE_{cir}$
Equation E46: Market clearing condition for margins summed across destinations to regional supplies $\sum_{i} XMAKE_{mip} = \sum_{d} PDOM_{pd}^{m}.XT_{pd}^{m,dom} + \sum_{r}\sum_{d} XMP_{rd}^{pm}$
Equation E47: Market clearing condition for sales summed across all users to supplies summed across regional origins $\sum_{u} X_{ud}^{cs}.P_{ud}^{cs} = PU_{ud}^{c}.XT1_{d}^{cs}$
J. Computation of Gross Regional Product (GRP)
Equation E48: GRP (expenditure approach) $GRPE_{d} = \sum_{u} P1_{ud}^{c}.X1_{ud}^{c} + \sum_{i} PTOT_{id}.XST_{id} - \sum_{c}\sum_{r} PBAS_{dr}^{c,imp}.XT_{dr}^{c,imp}$ $+ \sum_{m}(\sum_{dst} PMR_{dst,d}^{m}.XMR_{dst,s}^{m} - \sum_{p} PMR_{dp}^{m}.XMR_{dp}^{m})$ $+ \sum_{c}\sum_{s}(\sum_{dst} PBAS_{d,dst}^{cs}.XT_{d,dst}^{cs} - PBAS_{dd}^{cs}.XT_{dd}^{cs})$ $- \sum_{c}\sum_{s}(\sum_{org} PBAS_{org,dst}^{cs}.XT_{org,dst}^{cs} - PBAS_{dd}^{cs}.XT_{dd}^{cs})$
Equation E49: GRP (income approach) $GRPI_{d} = \sum_{i} PPRIM_{id}XPRIM_{id} + \sum_{i} VPTX_{id} + \sum_{u}\sum_{c}\sum_{r} PU_{sd}^{c}.XT1_{d}^{cs}.(T_{ud}^{cs} - 1)$

Table E1: Core equations of the TERM model (cont')

K. Others
Equation E50: Average propensity to consume $W3TOT_d = GRPI_d.\Psi_d$
Equation E51:Wage setting $W_{id}^{o} = W1_d.(P3_{cd}.X3_{cd} / W3TOT_d).FLAB_{iod}.FLAB_IO_d.FLABNAT$

Table E2: Variable descriptions

s/no	Variable name	Description
1.	$A2^{c}_{id}$	Basic investment technical change.
2.	$APRIM_{id}$	Primary factor augmenting technology change.
3.	$ATRADMAR^{csm}_{rd}$	Technology change for margin *m* on good *c,s* going from *r* to *d.*
4.	$FGOVTOT_{d}$	Government demand shifter by region *d*.
5.	$FGOV_{csd}$	Government demand shifter by commodity *c*, source *s* and region *d*.
6.	$FGOV_S_{cd}$	Government demand shifter by commodity *c* and region *d*.
7.	$FLAB_{iod}$	Wage shift variable by industry *i* occupation, *o* and region *d*.
8.	$FLAB_IO_{d}$	Wage shift variable by region *d*.
9.	$FLABNAT$	National wage shift variable.
10.	*FINV1*	Investment shift variable.
11.	$FP4NAT_{c}$	Export price shift variable.
12.	$FQ4_{c}$	Export quantity shift variable.
13.	FST_{id}	Inventory demand shift variable.
14.	$GRET_{id}$	Gross rate of return.
15.	$GGRO_{id}$	Gross growth rate of return.
16.	$Invslack$	Investment slack variable for exogenizing national investment.
17.	K_{id}	Demand for capital.
18.	L^{0}_{id}	Occupation-specific labour demands of industry users.
19.	$L1_{id}$	Labour composite demands of industry users.
20.	LND_{id}	Demand for land.
21.	N_{d}	Number of households in region *d*.
22.	P^{cs}_{ud}	Purchaser prices of commodities.
23.	$P1^{c}_{ud}$	Average price of domestic-import composite.
24.	$P11_{ud}$	Average price of intermediate goods composite.
25.	$P2TOT_{id}$	Cost of unit capital.
26.	$P4NAT_{c}$	Price of composite across all regions for export.

Table E2: Variable descriptions (cont')

s/no	Variable name	Description
27.	$PBAS_{r}^{cs}$	Basic prices of good.
28.	PC_{id}	Industry output price net of production taxes.
29.	PD_{rd}^{cs}	Delivered prices of goods.
30.	$PDOM_{cd}$	Basic domestic price of commodity *c* in region *d*.
31.	$PDOM_{cid}$	Basic domestic price of commodity *c* by industry *i* in region *d*.
32.	$PDOM_{r}^{m}$	Basic price of margin *m* by providers in region *p*.
33.	$PFIMP_{cd}$	Foreign import prices.
34.	$PI2_{id}$	Investment price index by industry.
35.	$PIMP_{cd}$	Price of import *c* in region *d*.
36.	PM_{rd}^{m}	Prices of margin *m* on goods from *r* to *d*.
37.	PMR_{rd}^{m}	Prices of composite margin *m* on goods from *r* to *d*.
38.	$PPRIM_{id}$	Primary factors composite prices.
39.	$PTOT_{id}$	Industry output price (inclusive of production taxes).
40.	PU_{sd}^{c}	User or delivered prices of source-composite goods.
41.	$RPTX_{id}$	Production tax rate.
42.	R_{id}	Rentals for capital.
43.	$RLAND_{id}$	Rentals for land.
44.	T_{ud}^{cs}	Powers of commodity taxes.
45.	$VPTX_{id}$	Production taxes revenue.
46.	W_{id}^{o}	Average occupation specific wages.
47.	$W1_{d}$	Average wages by region *d*.
48.	$W1_{id}$	Average labour composite wages.
49.	$WSUB_{d}$	Household aggregate subsistence expenditure.
50.	$W3TOT_{d}$	Household aggregate expenditure.
51.	X_{ud}^{cs}	Quantity demand of commodity *c* from source *s* by user *u* in region *d*.
52.	$X1_{ud}^{c}$	Quantity demand for domestic – import composite of commodity *c* by user *u* in region *d*.

Table E2: Variable descriptions (cont')

s/no	Variable name	Description
53.	$X11_{id}$	Quantity demand for intermediate goods composite.
54.	$X2^{c}_{id}$	Quantity of commodity *c* for investment by industry *i* in region *d*.
55.	$X2TOT_{id}$	Investment by industry.
56.	$X4NAT_{c}$	Export demand for composite across all regions.
57.	$XGOV_{cd}$	Quantity demands of government for commodity *c* in region *d*.
58.	$XPRIM_{id}$	Primary factor composite.
59.	$XSUB_{cd}$	Subsistence quantities per household.
60.	XST_{id}	Inventories
61.	XT^{cs}_{rd}	Quantity demand of goods *c,s* from *r* to *d*.
62.	$XT1^{cs}_{d}$	Quantity demand of sub-national source composite goods *c* in region *d*.
63.	$XMAKE_{cid}$	Supply of commodity *c* by industry *i* in region *d*.
64.	XMP^{pm}_{rd}	Quantity demand for margins to move goods from region *r* to *d*.
65.	XMR^{m}_{rd}	Quantity of composite margins *m* on goods from region *r* to *d* supplied by region *p*.
66.	$XTRADMAR^{csm}_{rd}$	Demand for margins *m*.
67.	$XTOT_{id}$	Industry outputs.
68.	$XMAKE_{cid}$	Output of good *c* by industry *i* in region *d*.
69.	Φ	Nominal exchange rate.
70.	β_{cd}	Marginal budget share of each commodity.
71.	Ψ_{d}	Average propensity to consume.
72.	γ	Export demand elasticity.

Table E3: Sets and set elements

Regions (r =1-5)	Taxes (t =1, 2)	Factors (v =1-3)
1. Inner Melbourne	1. Production tax	1. Labour
2. Middle Melbourne	2. Commodity tax	2. Capital
3. Outer Melbourne	**Users (u =1-5)**	3. Land
4. Rest of Victoria (RoV)	1. Producers	
5. Rest of Australia (RoA)	2. Investment	**Sources (s =1,2)**
	3. Households	1. Domestic
	4. Foreign demands	2. Imported
	5. Regional government	

Appendix F
Back-of-The-Envelope (BOTE) Analysis

F.1 BOTE of Wage Shock

According to Dixon et al. (2009), the short-run elasticity of demand for labour at a national level can be derived by starting with the elasticity of substitution (σ) between capital and labour which can be defined as follows.

$$l - k = -\sigma(w - q) \qquad \text{(Equation F1)}$$

where

- *l* is the percentage change in inputs of labour,
- *k* is the percentage change in inputs of capital,
- *q* is the percentage change in the price of labour; and
- *w* is the percentage change in the price of capital.

Dixon et al. (2009) explained that if intermediate inputs and taxes are ignored, then the zero pure-profit condition is:

$$S_k q + (1 - S_k)w = p \qquad \text{(Equation F2)}$$

where

- *p* is the percentage change in the product price; and
- S_k is the capital share in primary factor costs.

Substituting Equation F2 into F1, one obtains:

$$l - k = (-\sigma / S_k)(w - p) \qquad \text{(Equation F3)}$$

In the short run, k = 0, thus yielding the short-run elasticity of demand for labour (ε) with respect to the overall real wage as:

$$\varepsilon = -\sigma / S_k \qquad \text{(Equation F4)}$$

In the TERM database for Inner Melbourne region, σ is set at 0.15 for each industry while the average S_k across the various industries is about 0.44 – see column 1 of Table F1. Column 2 shows the ε value estimated for the various industries using Equation F4. The average ε for Inner Melbourne region was estimated to be about -0.545 (shown in column 2 of Table F1).

Using the short-run elasticity of demand for labour and the change in real wage (*w-p*) for individual industry, the BOTE analysis estimated the change in labour demand for each industry in Inner Melbourne region as shown in column 4 of Table F1. This was found to be close to that estimated by TERM as shown in column 5 of Table F1. The BOTE analysis estimated a weighted (according to wage share) drop of -0.9442% in labour demand for Inner Melbourne region due to an overall real wage shock of +2.09%. This is close to the -0.9478% estimated by TERM which suggests that the TERM model is behaving reasonably within standard labour market theory and data.

Table F1: BOTE analysis (+2.09% wage shock)

Industry	1 CAP	2 ε	3 w-p	4 lab_BOTE	5 lab_TERM	6 wage share	7 change in lab_BOTE
1 Primary	0.8775	-0.1709	2.1419	-0.3661	-0.3553	0.0041	-0.0015
2 FoodDrinks	0.5004	-0.2998	2.0129	-0.6034	-0.6012	0.0096	-0.0058
3 OthManufact	0.3806	-0.3941	1.9693	-0.7762	-0.7754	0.0657	-0.0510
4 Utilities	0.7112	-0.2109	2.2577	-0.4762	-0.4736	0.0077	-0.0036
5 Construction	0.5100	-0.2941	2.7150	-0.7985	-0.7983	0.0206	-0.0165
6 Trade	0.3413	-0.4395	1.4036	-0.6169	-0.6145	0.0991	-0.0612
7 HotelsCafes	0.3320	-0.4519	1.8910	-0.8544	-0.8546	0.0235	-0.0201
8 RoadTransprt	0.2185	-0.6865	0.8799	-0.6040	-0.6014	0.0052	-0.0031
9 RailTransprt	0.4426	-0.3389	1.8402	-0.6236	-0.6215	0.0017	-0.0011
10 OtherTrans	0.4845	-0.3096	2.2433	-0.6945	-0.6930	0.0086	-0.0060
11 WaterTrans	0.3403	-0.4408	1.8262	-0.8049	-0.8044	0.0010	-0.0008
12 AirTransport	0.2965	-0.5059	1.9272	-0.9749	-0.9770	0.0067	-0.0066
13 Communicatn	0.6663	-0.2251	2.3058	-0.5191	-0.5166	0.0231	-0.0120
14 BankInsure	0.5253	-0.2855	2.0955	-0.5984	-0.5961	0.1228	-0.0735
15 OwnerDwellng	0.9991	-0.1501	3.0464	-0.4574	-0.4549	0.0001	-0.0001
16 BusSrvces	0.3563	-0.4210	2.0540	-0.8647	-0.8650	0.2087	-0.1804
17 TechServic	0.0983	-1.5257	1.2010	-1.8323	-1.8616	0.1131	-0.2072
18 GovAdminDef	0.1383	-1.0848	1.2365	-1.3413	-1.3517	0.0387	-0.0519
19 EducHealth	0.0724	-2.0713	0.4984	-1.0324	-1.0349	0.1625	-0.1678
20 ChldCommCare	0.4312	-0.3478	0.9594	-0.3337	-0.3309	0.0048	-0.0016
21 OthServices	0.1909	-0.7857	1.2709	-0.9986	-1.0008	0.0725	-0.0724
Average	0.4435	-0.5448				Total	-0.9442

F.2 BOTE of Productivity Shock

From the employers' point of view, a drop in the productivity of the primary factor inputs (in particular labour) is equivalent to an increase in the real wage; an increase in real wage will bring down the labour demand. A preliminary productivity shock of -1% to *aprim ("InrMlbrnVic")* yielded an employment impact of about -0.230%. A BOTE analysis was also carried out to determine whether the TERM model is behaving reasonably and the results are shown in Table F2.

Table F2: Back-of-the-envelope analysis (*-1% aprim* shock)

Industry	1 CAP	2 ε	3 w-p	4 lab_BOTE	5 lab_TERM	6 wage share	7 change in lab_BOTE
1 Primary	0.8775	-0.1709	1.0771	-0.1841	-0.1803	0.0041	-0.0007
2 FoodDrinks	0.5004	-0.2998	0.6284	-0.1884	-0.1886	0.0096	-0.0018
3 OthManufact	0.3806	-0.3941	0.7937	-0.3128	-0.3139	0.0657	-0.0206
4 Utilities	0.7112	-0.2109	1.0367	-0.2187	-0.2191	0.0077	-0.0017
5 Construction	0.5100	-0.2941	0.9041	-0.2659	-0.2666	0.0206	-0.0055
6 Trade	0.3413	-0.4395	-0.5396	0.2371	0.2357	0.0991	0.0235
7 HotelsCafes	0.3320	-0.4519	0.6290	-0.2842	-0.2850	0.0235	-0.0067
8 RoadTransprt	0.2185	-0.6865	-0.4593	0.3153	0.3131	0.0052	0.0016
9 RailTransprt	0.4426	-0.3389	0.4300	-0.1457	-0.1458	0.0017	-0.0003
10 OtherTrans	0.4845	-0.3096	1.1304	-0.3499	-0.3514	0.0086	-0.0030
11 WaterTrans	0.3403	-0.4408	0.2126	-0.0937	-0.0937	0.0010	-0.0001
12 AirTransport	0.2965	-0.5059	0.6897	-0.3489	-0.3502	0.0067	-0.0023
13 Communicatn	0.6663	-0.2251	1.0711	-0.2412	-0.2417	0.0231	-0.0056
14 BankInsure	0.5253	-0.2855	0.9444	-0.2697	-0.2704	0.1228	-0.0331
15 OwnerDwellng	0.9991	-0.1501	0.6808	-0.1022	-0.1022	0.0001	0.0000
16 BusSrvces	0.3563	-0.4210	0.9388	-0.3952	-0.3971	0.2087	-0.0825
17 TechServic	0.0983	-1.5257	0.5123	-0.7817	-0.7900	0.1131	-0.0884
18 GovAdminDef	0.1383	-1.0848	0.3870	-0.4198	-0.4218	0.0387	-0.0163
19 EducHealth	0.0724	-2.0713	-0.0638	0.1322	0.1316	0.1625	0.0215
20 ChldCommCare	0.4312	-0.3478	-2.4657	0.8577	0.8439	0.0048	0.0041
21 OthServices	0.1909	-0.7857	0.1834	-0.1441	-0.1442	0.0725	-0.0105
Average	0.4076	-0.5448			Total	1.0000	-0.2282

In this instance, the elasticity of substitution σ was also set at 0.15 for each industry but an average capital share of 0.407 was estimated – see column 1 of Table F2. Column 2 shows the ε value estimated for the various industries using Equation F4. The average ε for Inner Melbourne region was estimated to be about -0.545 (shown in column 2 of Table F2).

Again, the short-run elasticity of demand for labour and the change in real wage (*w-p*) for individual industry were used in the BOTE analysis to estimate the change in labour demand for each industry in Inner Melbourne region due to the *aprim* shock. As shown in column 4 of Table F2, the BOTE estimated change in labour for each industry was found to be close to that estimated by TERM (as shown in column 5). The BOTE analysis estimated a weighted (according to wage share) drop of -0.228% in labour demand for Inner Melbourne region due to an *aprim* shock of -1%. This is close to the TERM's output of -0.230% which suggests that the TERM model is behaving reasonably.

Appendix G

Estimation of Productivity Shocks

This appendix presents the details of the calculation involved in the estimation of the productivity shocks associated with urban rail capacity constraint. The productivity shocks associated with a 10% rail capacity constraint have been estimated in this research using the PETE method i.e. the approach advocated in DfT's (2009) Transport Analysis Guide (Unit 3.5.14) and NZTA's (2008) Economic Evaluation Manual (Volume 1, Appendix A10).

As there are no corresponding elasticity estimates for Melbourne currently (PricewaterhouseCoopers, 2008), two sources of productivity elasticities were identified from secondary research for use in this thesis. These sources include the Department for Transport (DfT) (2009) and New Zealand Transport Agency (NZTA) (2008). Details of their agglomeration elasticity values are presented in Table G1.

Table G1: Details of agglomeration elasticity

Industry	Agglomeration Elasticity value	
	DfT (2009)	NZTA (2008)
Finance and Insurance	0.083	0.18
Business & Management Consultancy	0.083	0.167
Public admin, Education and Healthcare	0.083	0.292
Information Technology	0.083	0.082
Hotels & Restaurant	0.024	0.044
Wholesale & Retail	0.083	0.044
Labour recruitment	0.083	0.167
Real Estate	0.083	0.084
Construction	0.034	0.088
Electricity, gas & water	0.021	0.088
Manufacturing	0.021	0.024
Primary	0.021	0.024
Other services	0.083	0.127

The following methodology was adopted to shock the model to estimate the economic value of the productivity loss in the CBD due to rail capacity constraint:

- Step 1: Estimation of a weighted average agglomeration elasticity value for CBD;
- Step 2: Estimation of the weighted average generalised cost of travel to CBD; and
- Step 3: Estimation of the productivity loss for Melbourne CBD.

The details of each step are presented next.

Step 1: Estimation of a weighted average agglomeration elasticity value for CBD

In this step, a weighted-average productivity elasticity using the employment proportion of each sector in the CBD as weights was first calculated for Melbourne CBD. An example of the computation based on the agglomeration elasticity from DfT (2009) is shown in Table G2 below.

Table G2: Computation of a weighted average agglomeration elasticity – example based on values from DfT (2009)

Industry in Melbourne CBD	agglomeration elasticity based on DfT (2009)	total employment in each sector (CLUE data)	Product of elasticity & employment
Finance and insurance	0.083	41,542	3,448.0
Business & Management consultancy	0.083	47,139	3,912.5
Public admin, education and health	0.083	35,114	2,914.5
IT services	0.083	19,508	1,619.2
Wholesale and retail	0.024	15,738	377.7
Hotels and restaurant	0.024	16,861	404.7
Services	0.083	15,086	1,252.1
Real Estate	0.083	1,455	120.8
Electricity, gas and water	0.021	2,493	52.4
Construction	0.034	1,864	63.4
Manufacturing	0.021	1,977	41.5
Labour recruitment / personnel	0.083	111	9.2
Primary	0.021	1,612	33.9
Total		200,500	14,249.7
Weighted average=		**14,249.7 / 200,500 =**	**0.071**

The weighted average agglomeration elasticity value for Melbourne CBD based on the values of DfT (2009) is 0.071. The process is repeated using the agglomeration elasticity value from NZTA (2008). Table G3 summarises the weighted average agglomeration elasticity values derived.

Table G3: Weighted average agglomeration elasticity

Sources	Range of productivity elasticities
Department for Transport (2009)	0.07
New Zealand Transport Agency (2008)	0.14

Sources: NZTA (2008), DfT (2009) and CLUE (City of Melbourne, 2006)

It is observed from Table G3 that the weighted elasticity value estimated based NZTA (2008) is about twice that based on DfT (2009).

Step 2: Estimation of the weighted average generalised cost of travel to CBD

The weighted average generalised cost of all trips ($AGC^{S}_{CBD-Mel}$) across metropolitan Melbourne to the CBD in the AM peak was estimated using outputs from MITM based on Equation G1.

$$AGC^{S}_{CBD-Mel} = \sum_{m} D^{S,m}_{CBD-Mel} GC^{S,m}_{CBD-Mel} \Big/ \sum_{m} D^{m}_{CBD-Mel} \qquad \text{(Equation G1)}$$

where

- $GC^{S,m}_{CBD-Mel}$ is the average generalised cost of travel (from MITM);
- $D^{S,m}_{CBD-Mel}$ is the total demand on mode *m* for travel across metropolitan Melbourne to the CBD (from MITM);
- S is the Base Case or Option scenario (i.e. a 10% rail capacity constraint) ; and
- m is the mode of travel i.e. private auto or public transport (PT) mode.

The PETE method works out the average generalised cost of travel on each mode for each origin-CBD pair. Instead of doing so, this assessment simplified the computation by estimating an average $GC^{S,m}_{CBD-Mel}$ value for the private and PT mode across all origins of various distance bands from the CBD weighted according to their travel demands.

NZTA (2008) highlighted that the weights ($D^{S,m}_{CBD-Mel}$) need to be identical for the Base Case and option scenarios; however, no such conditions were specified by DfT (2009). This research adhered strictly to the weights requirement specified by each method.

Information from MITM suggests that in the Base Case, about 12,850 trips made into the CBD in the AM peak are undertaken in the private auto mode while another 98,850 are carried out on public transport (PT). These weights were used for the computation with the NZTA (2008) values.

As reported in Chapter 5, the MITM modelling only involves a Highway Assignment simulation. Hence, an outside calculation was carried out to estimate the total amount of public transport trips under a 10% rail capacity constraint scenario. Of the 98,854 PT trips, information from MITM suggests that 67,304 are train trips; the remaining 31,550 are tram / bus trips. For this calculation, it was estimated that 10% of the 67,304 train users (or 6,730 users) are affected under a 10% rail capacity scenario; the remaining 60,574 rail users would continue to use the train. It was established in Chapter Five that 18% of the affected rail users would switch to tram and buses. This means that about 1,211 affected rail users would switch to tram / buses (i.e. 18% * 6,730), thus bringing the total tram / bus users to 32,761. The resultant total PT users is therefore 93,335.

Results of the MITM modelling suggest that there is no noticeable change in the generalised cost of PT users (i.e. $13.79) for AM peak travel into the CBD in the Base Case and test scenario. However, the diverted rail-to-car users are envisaged to increase the cost of private auto trips in the CBD from $18.00 to $18.68 under a 10% rail capacity constraint scenario. These figures were used to estimate the weighted average generalised cost of travel into the CBD using the agglomeration elasticity shown in Table G3. The results are presented in Table G4.

Table G4: Weighted average generalised cost of travel into CBD (AM peak) for Base Case and Option scenario (i.e. a 10% rail capacity constraint) – based on MITM output

		Auto mode	**PT mode**
Base Case	Total demand (trips)	12,850	98,850
	Average generalised cost / trip	$18.00	$13.79
	Weighted average generalised cost / trip	**$14.27**	
Option scenario – <u>different</u> weights; DfT's (2009) approach	Total demand (trips)[1]	14,780	93,340
	Average generalised cost / trip	$18.68	$13.79
	Weighted average generalised cost / trip	**$14.46**	
Option scenario – <u>identical</u> weights; NZTA's (2008) approach	Total demand (trips)	12,850	98,850
	Average generalised cost / trip	$18.68	$13.79
	Weighted average generalised cost / trip	**$14.35**	

[1] The PT demand for the DfT (2009) approach was estimated outside MITM by reducing the train demand into CBD (from MITM) by 10% and assuming that 18% of the affected rail commuters switch to trams and buses (as based on HLB (2003); the auto demand was generated by MITM based on the highway assignment conducted as outlined in Section 5.4.

In this instance, it is observe that the weighted average generalised cost estimated using the NZTA's (2008) approach is lower than that based on DfT (2009). Consultation with both DfT and NZTA[2] suggested that that the slight variation in their approaches may be due to their minor differences in the interpretation of Graham's (2005, 2006a, 2006b, 2007b) work. Observation, however, suggests that the slight variation in their weights requirement is probably to compensate for their differences in the elasticity values - it is observed that while the NZTA's (2008) agglomeration elasticities are higher than DfT's (2009), they compensate the higher elasticities by using identical travel demands (i.e. $D^{S,m}_{CBD-Mel}$) which yielded lower estimates of the average generalised cost of travel – see Table G4.

Step 3: Estimation of the productivity loss for Melbourne CBD

The average generalised costs of travel derived in step (2) were used to estimate the degeneration in the effective employment densities for Melbourne CBD due to a 10% rail capacity constraint in the AM peak. Based on DfT's (2009) and NZTA's (2008) definition, the effective employment density (ED^{S}_{CBD}) in this instance measures the accessibility of all workers in metropolitan Melbourne to firms in the CBD based on the functional form shown in Equation G2.

$$ED^{S}_{CBD} = \frac{E^{S}_{Mel}}{AGC^{S}_{CBD-Mel}} \qquad \text{(Equation G2)}$$

where

- E^{S}_{Mel} is the total employment in metropolitan Melbourne in the scenario *S*;
- $AGC^{S}_{CBD-Mel}$ is the average generalised cost of travel in the AM peak from metropolitan Melbourne to the CBD in the scenario S; and
- S is the Base Case or Option scenario (i.e. a 10% rail capacity constraint).

[2] Obtained via personal communication.

Equation G3 estimates the productivity loss to the CBD due to dis-agglomeration associated with a 10% rail capacity constraint.

$$\delta PR_{CBD} = (\frac{ED_{CBD}^{Option}}{ED_{CBD}^{BaseCase}})^{\rho} - 1 \qquad \text{(Equation G3)}$$

where

- δPR_{CBD} is relative reduction in the CBD's productivity; and
- ρ is the weighted average agglomeration elasticity presented in Table G3.

As the total employment in metropolitan Melbourne for both the Base Case and the Option scenario is not expected to fluctuate for a particular time period, Equation G3 can be re-written as Equation G4.

$$\delta PR_{CBD} = (\frac{AGC_{CBD}^{BaseCase}}{AGC_{CBD}^{Option}})^{\rho} - 1 \qquad \text{(Equation G4)}$$

The weighted average agglomeration elasticities shown in Table G3 and the respective weighted average generalised cost of travel presented in Table G4 were then inputted into Equation G4 to estimate the productivity shocks. These are presented in Table G5.

Table G5: Productivity shocks (associated with a 10% rail capacity constraint) for Melbourne CBD

Sources	Productivity shocks
DfT (2009)	-0.09%
NZTA (2008)	-0.08%

As shown in Table G5, the productivity shocks for Melbourne CBD estimated based on DfT's (2009) and NZTA's (2008) method and their respective agglomeration elasticities are very close in value. This is reasonable since both methods and their respective elasticities were based on the same work of Graham (2005, 2006a, 2006b, 2007b) and the productivity shocks were estimated for the same CBD. The above outcome appears to support the earlier proposition that the slight variation in the way that DfT (2009) and NZTA (2008) estimate the weighted average generalised cost of travel ($AGC_{CBD-Mel}^{S}$) is to offset the differences in their agglomeration elasticity values. The shocks shown in Table G5 were imposed on TERM and the results are presented in Section 8.6.

References

ABELSON, P. (2009) The Wider Economic Benefits of Transport: A Review. *Applied Economics,* In-press.

ABERG, Y. (1973) Regional Productivity Differences in Swedish Manufacturing. *Regional and Urban Economics,* vol. 3 no.2**,** 131-156.

ADAMS, P. D. (2007) Insurance Against Catastrophic Climate Change : How Much Will An Emissions Trading Scheme Cost Australia? *Australian Economic Review,* Vol 40**,** 432 - 52.

ADAMS, P. D., HORRIDGE, J. M. & WITTWER, G. (2002) MMRF-Green: A Dynamic Multi-Regional Applied General Equilibrium Model of the Australian Economy, based on the MMR and Monash Models. *Prepared for the Regional GGE Modelling Course (25-29 Nov 2002).* Melbourne, Centre of Policy Studies (Monash University).

ADAMS, P. D. & PARMENTER, B. R. (1994) Microeconomic Reform and Employment in the Short Run. *The Economic Record,* vol 70 no 208**,** 1-11.

ADDARIO, S. D. & PATACCHINI, E. (2006) Is there an Urban Wage Premium in Italy? *Banca D'Italia,* No. 570.

ADELAIDE CITY COUNCIL. Boundary of Adelaide CBD. [online]. Message to: GWEE, E. [Accessed 10 July 2009]. Personal communication.

ASCHAUER, D. A. (1989) Is Public Expenditure Productive. *Journal of Monetary Economics,* 23**,** 177 - 200.

AUSTRALIAN BUREAU OF STATISTICS (2001a) 1321.0 - Small Business in Australia.

AUSTRALIAN BUREAU OF STATISTICS (2001b) Census of Population and Housing - Industry of Employment by Occupation: Melbourne (c) S'bank-D'lands, Melbourne (c) Remainder, Stonnington (Prahran), Glen Eira (Caufield), Darebin (Northcote), Moreland (Coburg), Moreland (Brunswick), Moonee Valley (Essendon), Maribyrnong, Hobsons Bay (Williamstown) SLAs and Yarra, Port Philip, Boroondara LGAs (based on place of employment)

AUSTRALIAN BUREAU OF STATISTICS (2006a) Basic Community Profile (Victoria State): Cat. No. 2006.2001.0.

AUSTRALIAN BUREAU OF STATISTICS (2006b) Census of Population and Housing-Industry of Employment by Occupation - Melbourne (C) Inner Statistical Local Area (based on place of employment).

AUSTRALIAN BUREAU OF STATISTICS (2006c) Census of Population and Housing - Count of Persons (Excludes Overseas Visitor) : Melbourne (C) Inner Statistical Local Area (based on place of usual residence)

AUSTRALIAN BUREAU OF STATISTICS (2006d) Census of Population and Housing - Industry of Employment by Occupation (Perth (C) - Inner Statistical Local Area) - based on Place of Employment.

AUSTRALIAN BUREAU OF STATISTICS (2006e) Census of Population and Housing - Industry of Employment by Occupation: Australia (based on place of employment).

AUSTRALIAN BUREAU OF STATISTICS (2006f) Census of Population and Housing - Industry of Employment by Occupation: Inner Melbourne Region [Melbourne (C), Port Philip (C), Yarra (C), Stonnington (C) Prahan SLA] (based on place of employment)

AUSTRALIAN BUREAU OF STATISTICS (2006g) Census of Population and Housing - Industry of Employment by Occupation: Melbourne (c) S'bank-D'lands, Melbourne (c) Remainder, Stonnington (Prahran), Glen Eira (Caufield), Darebin (Northcote), Moreland (Coburg), Moreland (Brunswick), Moonee Valley (Essendon), Maribyrnong, Hobsons Bay (Williamstown) SLAs and Yarra, Port Philip, Boroondara LGAs (based on place of employment)

AUSTRALIAN BUREAU OF STATISTICS (2006h) Census of Population and Housing - Industry of Employment by Occupation: Middle Melbourne Region [Western Melbourne, Moreland City, North Middle Melbourne, Boroondara City, East Middle Melbourne and Southern Melbourne Statistical Sub-Divisions] (based on place of employment).

AUSTRALIAN BUREAU OF STATISTICS (2006i) Census of Population and Housing - Industry of Employment by Occupation: Outer Melbourne Region [Melton-Wyndham, Hume City, North Outer Melbourne, Yarra Ranges Shire Part A, Greater Dandenong City, Frankston City, Mornington Peninsula Shire and Southern Eastern Melbourne Statistical Sub-Divisions] (based on place of employment).

AUSTRALIAN BUREAU OF STATISTICS (2006j) Census of Population and Housing - Industry of Employment by Occupation: State of Victoria (based on place of employment).

AUSTRALIAN BUREAU OF STATISTICS (2006k) Census of Population and Housing - Method of Travel to Work by Occupation (Perth (C) - Inner Statistical Local Area) - based on Place of Employment.

AUSTRALIAN BUREAU OF STATISTICS (2006l) Census of Population and Housing : Occupation by Gross Individual Income (Weekly) by Age - Melbourne (c) Inner (Place of Work - Statistical Local Area)

AUSTRALIAN BUREAU OF STATISTICS (2006m) Census of Population and Housing : Occupation by Gross Individual Income (Weekly) by Age - Melbourne Statistical Division (based on Place of Employment)

AUSTRALIAN BUREAU OF STATISTICS (2009a) 2006 Census of Population and Housing - Method of Travel to Work for Place of Destination zones in Adelaide Statistical Division (Customised Data Report).

AUSTRALIAN BUREAU OF STATISTICS (2009b) 2006 Census of Population and Housing - Method of Travel to Work for Place of Destination zones in Brisbane Statistical Division (Customised Data Report).

AUSTRALIAN BUREAU OF STATISTICS (2009c) 2006 Census of Population and Housing - Method of Travel to Work for Place of Destination zones in Melbourne Statistical Division (Customised Data Report).

AUSTRALIAN BUREAU OF STATISTICS (2009d) 5220.0 - Australian National Accounts: State Accounts (2008 - 09) (Reissue).

AUSTRALIAN BUREAU OF STATISTICS (2009e) Australian Standard Geographical Classification (ASGC) - Victoria Maps.

AUSTRALIAN TRANSPORT COUNCIL (2006) National Guidelines for Transport System Management in Australia. IN AUSTRALIAN TRANSPORT COUNCIL (Ed.

AUSTROADS (2006) Update of RUC Unit Values to June 2005. *Austroads Technical Report AP-T70/06.* Sydney, Austroads.

BAILEY, N. & TUROK, I. (2001) Central Scotland as a Polycentric Urban Region : Useful Planning Concept or Chimera ? *Urban Studies,* vol 38 no 4**,** 697 - 715.

BARTLEY CONSULTING PTY LTD (2008) Walking and Cycling: Census Analysis. Melbourne Australia, Department of Transport.

BATTEN, D. F. (1995) Network Cities: Creative Urban Agglomerations for the 21st Century. *Urban Studies,* vol 32 no 2**,** 313-327.

BEESON, P. (1990) Sources of the Decline of Manufacturing in Large Metropolitan Areas. *Journal of Urban Economics,* vol. 28**,** 71-86.

BERGSMAN, J., GREENSTON, P. & HEALY, R. (1972) The Agglomeration Process in Urban Growth. *Urban Studies,* Vol 9, no. 3**,** 263-288.

BLUMSTEIN, A. & MILLER, H. (1983) Making Do: The Effects of a Mass Transit Strike on Travel Behaviour. *Transportation,* Vol 11**,** 361 - 382.

BOOZ ALLEN HAMILTON (2003) Passenger Transport Demand Elasticities *Transfund New Zealand Research Programme 2000 - 2001.* Wellington.

BRAIN, P. (1977) The Institute Multi-Purpose Model : An Outline. *The Australian Economic Review,* 3rd Quarter**,** 47-64.

BRAIN, P. (1986) *The Microeconomic Structure of the Australian Economy,* Melbourne Longman Cheshire Pty Limited.

BRISBANE CITY COUNCIL (2006) Brisbane City Centre - Master Plan 2006.

BRISBANE CITYTRAIN. Information on the Rolling Stock and Carrying Capacity of Brisbane system. [online]. Message to: GWEE, E. [Accessed 22 June 2009]. Personal communication.

BRISBANE CITYTRAIN (2009b) Introducing the CityTrain Fleet.

BRISBANE CITYTRAIN (2009c) Train Timetables and Map. Brisbane.

BROCKER, J. (1995) Chamberlinian Spatial Computable General Equilibrium Modelling: A Theoretical Framework. *Economic Systems Research,* Vol. 7**,** 137 - 149.

BROCKER, J. (1998) Operational Computable General Equilibrium Modeling. *Annals of Regional Science,* Vol. 32**,** 367 - 387.

BROCKER, J. (2002) Spatial Effects of European Transport Policy : A CGE Approach. IN HEWINGS, G. J. D., SONIS, M. & BOYCE, D. (Eds.) *Trade, Networks and Hierarchies: Modeling Regional and Interregional Economics.* Berlin, Springer.

BROCKER, J. (2004) Computable General Equilibrium Analysis in Transportation Economics. IN HENSHER, D., BUTTON, K. J., HAYNES, K. E. & STOPHER, P. (Eds.) *Handbook of Transport Geography and Spatial Systems.* Amsterdam, Elsevier BV.

BUCKLEY, P. H. (1992) A Transport-Oriented Interregional Computable General Equilibrium Model of the United States. *Annals of Regional Science,* Vol 26**,** 331-348.

BURNS, M. & SHANAHAN, M. (2000) Labour Market Models and Their Use in Projecting Vocational Education and Training Requirements. Kensington Park SA, National Centre for Vocational Education Research.

CALEM, P. S. & CARLINO, G. A. (1991) Urban Agglomeration Economies in the Presence of Technical Change. *Journal of Urban Economics,* vol 29**,** 82-95.

CARLINO, G. A. (1978) *Economies of Scale in Manufacturing Location - Theory and Measure,* Leiden Boston, Martinus Nijhoff Social Science Division.

CARLINO, G. A. (1980) Contrasts in Agglomeration: New York and Pittsburgh Reconsidered. *Urban Studies,* vol 17 no 3**,** 343 - 351.

CERVERO, R. (1990) Transit Pricing Research - A Review and Synthesis. *Transportation,* Vol 17**,** 117 - 139.

CERVERO, R. (2001) Efficient Urbanisation: Economic Performance and the Shape of the Metropolis. *Urban Studies,* vol 38 no 10**,** 1651 - 1671.

CICCONE, A. (2002) Agglomeration Effects in Europe. *European Economic Review,* 46 213-227.

CICCONE, A. & HALL, R. E. (1996) Productivity and the Density of Economic Activity. *The American Economic Review,* Vol. 86 no. 1**,** 54-70.

CITY OF MELBOURNE (2006) Census of Land Use and Employment (CLUE). City of Melbourne.

CITY OF MELBOURNE. 2006 Census of Land Use and Employment - Total CBD Establishments by Employment Size and Industry. [online]. Message to: GWEE, E. [Accessed 8 Dec 2009]. Personal communication.

CITY OF PERTH. Boundary of Perth CBD. [online]. Message to: GWEE, E. [Accessed 23 June 2009]. Personal communication.

CITYRAIL. Average Number of Carriages per Train and Allowable Average Passenger Loading per Train [online]. Message to: GWEE, E. 17 June 2009. [Accessed Personal communication.

CITYRAIL (2009b) CityRail Timetables. Sydney.

CITYRAIL (2009c) Information on the Rolling Stock of CityRail. Sydney.

CLICHE, D. & REID, S. (2007) Growing Patronage - Think Tram ? *10th International Conference on Competition and Ownership in Land Passenger Transport* Hamilton Island, Australia.

COINDET, J. (1998) Home-to-work Trips During the Transportation Strikes in Ile-de-France at the end of 1995. *Journal of Transportation and Statistics 1* Vol 3**,** 43 - 51.

CONNEX MELBOURNE (2008) Connex Melbourne Trains Australia - Fast Facts.

CONNEX MELBOURNE. Melbourne Metropolitan Train Operational Characteristics. [online]. Message to: GWEE, E. 27 May 2009. [Accessed 27 May 2009]. Personal communication.

CONRAD, K. & SEITZ, H. (1994) The Economic Benefits of Public Infrastructure. *Applied Economics,* vol 26**,** 303 - 311.

CRAMPTON, G. & EVANS, A. (1992) The Economy of an Agglomeration: The Case of London. *Urban Studies,* vol 29 no 2**,** 259-271.

CURRIE, G. (2007) *Postgraduate Program in Transport and Traffic- Unit CIV 5316: Fundamentals of Urban Public Transport (2nd Edition),* Melbourne, Institute of Transport Studies (Monash University).

CURRIE, G., MUHAMMAD, I. & SENBERGS, Z. (2006) Metlink Market Futures Research and Development Project: Phase 1 - Identification of Potential Market Change Factors (Report 1 Literature Review). Melbourne, Institute of Transport Studies, Monash University.

CURRIE, G. & SENBERGS, Z. (2007) Identifying Spatial Gaps in Public Transport Provision for Socially Disadvantaged Australians - The Melbourne 'Needs Gap' Study. *30th Australasian Transport Research Forum.* Melbourne, Australia.

DAVIS, J. C. & HENDERSON, V. (2008) The Agglomeration of Headquarters. *Regional Science and Urban Economics,* vol 38**,** 445 - 460.

DEPARTMENT FOR TRANSPORT (2006) Transport, Wider Economic Benefits and Impacts on GDP.

DEPARTMENT FOR TRANSPORT (2009) Transport Analysis Guidance 3.5.14 - The Wider Impacts Sub-Objective.

DEPARTMENT FOR TRANSPORT. Estimation of Agglomeration Impacts - query on how such effects are considered in CBA. [online]. Message to: GWEE, E. [Accessed 3 Feburary 2010]. Personal communication.

DEPARTMENT OF INFRASTRUCTURE (2005a) Annual Report (2004 - 2005). IN DEPARTMENT OF INFRASTRUCTURE (Ed., Department of Infrastructure.

DEPARTMENT OF INFRASTRUCTURE (2005b) Guideline on Economic, Social and Environmental Cost-Benefit Analysis.

DEPARTMENT OF INFRASTRUCTURE (2006) Annual Report (2005 - 2006). IN DEPARTMENT OF INFRASTRUCTURE (Ed., Department of Infrastructure.

DEPARTMENT OF INFRASTRUCTURE (2007) Annual Report (2006 - 2007). IN DEPARTMENT OF INFRASTRUCTURE (Ed., Department of Infrastructure.

DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT (2005) VicMap - Melbourne Metropolitan Local Government Areas.

DEPARTMENT OF TRANSPORT (2008a) Annual Report (2007 - 2008). Melbourne, Department of Transport.

DEPARTMENT OF TRANSPORT (2008b) Invitation to Tender Melbourne Metropolitan Train Franchise Vol 1 - Tendering Information and Evaluation Criteria.

DEPARTMENT OF TRANSPORT (2008c) Overview of the Melbourne Multi-Modal Integrated Transport Model IN DEPARTMENT OF TRANSPORT (Ed.

DEPARTMENT OF TRANSPORT. Representation Year of MITM Base Case. [online]. Message to: GWEE, E. [Accessed 23 Dec 2008]. Personal communication.

DEPARTMENT OF TRANSPORT (2008e) Travel Demand Information Atlas for Victoria. IN DEPARTMENT OF TRANSPORT (Ed.

DEPARTMENT OF TRANSPORT (2009a) Annual Report (2008 - 2009). Melbourne, Department of Transport.

DEPARTMENT OF TRANSPORT (2009b) The Victorian Transport Plan. Department of Transport (Victoria).

DEPARTMENT OF TRANSPORT (2010) MITM - Providing New Capabilities for Modelling Melbourne. *Transport Research and Policy Analysis Bulletin,* Winter, Issue 10.

DEPARTMENT OF TRANSPORTATION (2010) TIGER II Discretionary Grant Program Final Notice Federal Register Vol 75 no. 104.

DIXON, P. B., MADDEN, J. & RIMMER, M. T. (2009) Linking National and Multi-regional Computable General Equilibrium (CGE) Models: The Effects of an Increase in Award Wage Rates in Australia *Regional Studies,* Vol. 1**,** 1-17.

DIXON, P. B. & PARMENTER, B. R. (1994) *Computable General Equilibrium Modelling,* Melbourne, Centre of Policy Studies Monash University.

DIXON, P. B., PARMENTER, B. R., POWELL, A. & WILCOXEN, P. J. (1992) *Notes and Problems in Applied General Equilibrium Economics,* Amsterdam, North-Holland Publishing Company.

DIXON, P. B., PARMENTER, B. R. & RIMMER, M. T. (2002a) CGE Models for Practical Policy Analysis - The Australian Experience. IN FOSSATI, A. & WIEGARD, W. (Eds.) *Policy Evaluation with Computable General Equilibrium Models.* London, Routledge.

DIXON, P. B., PARMENTER, B. R., RYLAND, G. J. & SUTTON, J. (1982) ORANI: A General Equilibrium Model of the Australian Economy - First Progress Report of the IMPACT Project (Vol. 2). Canberra, Australian Government Publishing Service.

DIXON, P. B., PARMENTER, B. R. & SUTTON, J. (1978) Spatial Disaggregation of ORANI results: A preliminary Analysis of the Impacts of Protection at the State level. *Economic Analysis and Policy,* Vol. 8**,** 35-86.

DIXON, P. B., PICTON, M. R. & RIMMER, M. T. (2002b) Efficiency Effects of Inter-Government Financial Transfers in Australia. *AusTralian Economic Review,* Vol.35 no. 3**,** 304 - 315.

DIXON, P. B. & RIMMER, M. T. (2002) *Dynamic General Equilibrium Modelling for Forecasting and Policy: A Practical Guide and Documentation of MONASH,* Amsterdam, North-Holland Publishing Company.

DIXON, P. B. & RIMMER, M. T. (2010) Johansen's Contribution to CGE Modelling: Originator and Guiding Light for 50 Years. *Symposium in memory of Professor Leif Johansen and Celebration of the Fifieth Anniversary of the Publication of His "A Multi-Sectoral Study of Economic Growth" (North Holland 1960) - 20-21 May 2010.* The Norwegian Academy of Science and Letters, Oslo.

DIXON, P. B., RIMMER, M. T. & TISIGAS, M. E. (2007) Regionalizing Results from a Detailed CGE Model: Macro, Industry and State Effects in the U.S. of Removing Major Tariffs and Quotas. *Paper in Regional Science,* Vol. 86 (1)**,** 31-55.

DSG (2009) Metropolitan Copenhagen Commuter Rail Network Map, Timetables and Rolling Stock Information.

DUFFY-DENO, K. T. & EBERTS, R. W. (1989) Working Paper 8909 - Public Infrastructure and Regional Economic Development : A Simultaneous Equations Approach. Federal Reserve Bank of Cleveland.

EBERTS, R. W. (1986) Working Paper 8610 - Estimating the Contribution of Urban Public Infrastructure to Regional Growth. Federal Reserve Bank of Cleveland.

EBERTS, R. W. (1990a) Public Infrastructure and Regional Economic Development. *Economic Review, Federal Reserve Bank of Cleveland,* Quarter 1**,** 15 - 27.

EBERTS, R. W. (1990b) Working Paper 9004 - Cross-Sectional Analysis of Public Infrastructure and Regional Productivity Growth. Federal Reserve Bank of Cleveland.

EBERTS, R. W. & MCMILLEN, D. P. (1999) Agglomeration Economics and Urban Public Infrastructure. IN CHESHIRE, P. & MILLS, E. S. (Eds.) *Handbook of Regional and Urban Economics (Vol 3 Applied Urban Economics).* Amsterdam, Elsevier Science B.V.

EDDINGTON, R. (2006a) The Eddington Transport Study - Main report: Transport's Role in Sustaining the UK's Productivity and Competitiveness. London.

EDDINGTON, R. (2006b) The Eddington Transport Study - The case for action: Sir Rod Eddington's Advice to Government. London, Her Majesty's Treasury.

EDDINGTON, R. (2008) Investing in Transport - East West Link Needs Assessment (A Study by Sir Rod Eddington). Melbourne.

EIJGENRAAM, C. J. J., KOOPMANS, C. C., TANG, P. J. G. & VERSTER, A. C. P. (2000a) Evaluation of Infrastructural Projects - Section 1: Main Report. IN MINISTRY OF TRANSPORT PUBLIC WORKS AND WATER MANAGEMENT AND THE MINISTRY OF ECONOMIC AFFAIRS (Ed.

EIJGENRAAM, C. J. J., KOOPMANS, C. C., TANG, P. J. G. & VERSTER, A. C. P. (2000b) Evaluation of Infrastructural Projects - Section 2: Capita Selecta. IN MINISTRY OF TRANSPORT PUBLIC WORKS AND WATER MANAGEMENT AND THE MINISTRY OF ECONOMIC AFFAIRS (Ed.

ELHORST, J., OOSTERHAVEN, J. & ROMP, W. (2004) Integral Cost-Benefit Analysis of Maglev Technology Under Market Imperfections. IN SOM RESEARCH REPORT (Ed., University of Groningen.

ELLISON, R. (1995) Melbourne's Public Transport Services. *Urban Futures,* no 20 pages 33-45.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT (2001) *Assessing The Benefits Of Transport,* France, OECD Publications.

EXEL, N. J. A. V. & RIETVELD, P. (2001) Public Transport Strikes and Traveller Behaviour. *Transport Policy,* Vol 7 no 3**,** 227-246.

FAULCONBRIDGE, J. R. (2007) London's and New York's Advertising and Law Clusters and Their Networks of Learning: Relational Analyses with a Politics of Scale ? *Urban Studies,* vol 44 no 9**,** 1635 - 1656.

FEDERAL TRANSIT ADMINISTRATION (2007) Procedures & Technical Methods for Transit Project Planning (Alternatives Analysis Technical Guidance). IN UNITED STATES DEPARTMENT OF TRANSPORTATION (Ed.

FIELD, A. (2009) *Discovering Statistics Using SPSS (3rd Edition),* Singapore, SAGE Publications Asia-Pacific Pte Ltd.

FISHLOW, A. (1965) *American Railroads and the Transformation of the Ante-Bellum Economy,* Cambridge, Massachusetts, Harvard University Press.

FOGEL, R. W. (1964) *Railroads and American Economic Growth: Essays in Econometric History,* Baltimore, The John Hopkins Press.

FUJITA, M., KRUGMAN, P. & VENABLES, A. J. (1999) *The Spatial Economy: Cities, Regions and International Trade,* Cambridge Mass, MIT Press.

GARCIA-MILA, T. & MCGUIRE, T. (1992) The Contribution of Publicly Provided Inputs to States' Economies. *Regional Science and Urban Economics,* 22**,** 229-241.

GARROD, G. & WILLIS, K. G. (1999) *Economic Valuation of the Environment - Methods and Case Studies,* Cheltenham UK, Edward Elgar.

GHK INTERNATIONAL (CANADA) LTD (2000) The Future of Downtown Toronto - A Report Prepared for the City of Toronto (Urban Services Development Department). Toronto, City of Toronto (Urban Services Development Department).

GIBBONS, S. & MACHIN, S. (2003) Rail access and house prices : an evaluation of the wider economic benefits of transport improvements London, Centre for Economic Performance, London School of Economics.

GIBBONS, S. & OVERMAN, H. (2009) Productivity in Transport Evaluation Studies. London, Department for Transport.

GIESECKE, J. A. (2002) Explaining Regional Economic Performance: An Historical Application of a Dynamic Multi-Regional CGE Model. *Papers in Regional Science,* Vol. 81 (2)**,** 247-278.

GIESECKE, J. A. (2003) Targeting Regional Output with State Government Fiscal Instruments: A Dynamic Multi-Regional CGE Analysis. *Australian Economic Papers,* Vol. 42 (2)**,** 214-233.

GIESECKE, J. A. & MADDEN, J. R. (1997) Regional Government Economic Policy: Assessing the Policy Instruments. *Australasian Journal of Regional Studies,* Vol. 3 (1) 3-18.

GOMEZ-IBANEZ, J. A. (1991) A Global View of Automobile Dependence - A Book Review of "Cities and Automobile Dependence: An International Sourcebook" by Newman, P and Kenworthy, J. *Journal of American Planning Association,* Vol. 57 Issue 3**,** 376-380.

GOOGLE MAPS AUSTRALIA (2009) Maps of Melbourne, Sydney, Brisbane, Adelaide and Perth CBDs.

GRAHAM, D. (2000) Spatial Variation in Labour Productivity in British Manufacturing. *International Review of Applied Economics,* Vol 14 no.3**,** 323-341.

GRAHAM, D. (2001) Productivity Growth in British Manufacturing: Spatial Variation in the Role of Scale Economies, Technological Growth and Industrial Structure. *Applied Economics,* vol. 33 no.6**,** 811-821.

GRAHAM, D. (2005) Wider economic benefits of transport improvements: link between agglomeration and productivity (Stage 1 report). London, Centre for Transport Studies, Imperial College London :DfT.

GRAHAM, D. (2006a) Investigating the link between productivity and agglomeration for UK industries. London, Centre for Transport Studies, Imperial College London.

GRAHAM, D. (2006b) Wider economic benefits of transport improvements : link between agglomeration and productivity (Stage 2 report). London, Centre for Transport Studies, Imperial College London : DfT.

GRAHAM, D. (2007a) Agglomeration Econommics and Transport Investment. *ITF Round Tables - The Wider Economic Benefits of Transport: Macro-Meso- and Micro-Economic Transport Planning and Investment Tools.* Boston, USA (25-26 October 2007).

GRAHAM, D. (2007b) Agglomeration, Productivity and Transport Investment. *Journal of Transport Economics and Policy,* Vol 41 Part 3**,** 317 - 343.

GRAHAM, D. (2009) Identifying Urbanisation and Localisation Externalities in Manufacturing and Service Industries. *Papers in Regional Science,* vol. 88 no.1**,** 63-84.

GRAHAM, D. & VAN DENDER, K. (2009) Discussion Paper No. 2009 - 32: Estimating the Agglomeration Benefits of Transport Investments: Some Tests for Stability. OECD / ITF Joint Transport Research Centre.

GREEN, S. B. (1991) How Many Subjects does it take to do a Regression Analysis? . *Multivariate Behavioral Research,* Vol. 26 no.3**,** 499-510.

GROENEWOLD, N., MADDEN, J. R. & HAGGER, A. J. (2003) The Effects of Interregional Transfers: A Political-Economy CGE Approach. *Papers in Regional Science,* Vol. 82 no. 4**,** 535 - 554.

GWEE, E., CURRIE, G. & STANLEY, J. (2008) Evaluating Urban Railway Development Projects - An International Comparison. *Australian Transport Research Forum 2008.* Gold Coast, Australia.

GWEE, E. & MADDEN, J. R. (2010) A Spatial CGE Model for Assessing the Vulnerability of Regional Economies to Transport System Failures. *57th Annual North American Meeting of the Regional Science Association International (10 - 13 November 2010).* Denver (USA).

HADDAD, E. A. (1999) *Regional Inequality and Structural Changes: Lessons from the Brazalian Experience,* Ashgate, Aldershot.

HADDAD, E. A. & HEWINGS, G. J. D. (2005) Market Imperfections in a Spatial Economy: Some Experimental Results. *The Quarterly Review of Economics and Finance,* Vol. 45**,** 476-496.

HAIR, J. F., BLACK, W. C., BABIN, B. J., ANDERSON, R. E. & TATHAM, R. L. (2006) *Multivariate Data Analysis (6th Ed),* New Jersey, Pearson Prentice Hall.

HALL, P. & HASS-KLAU, C. (1985) *Can Rail Save the City?,* Aldershot, Gower Publishing Company Limited.

HANSEN, E. R. (1990) Agglomeration Economies and Industrial Decentralization: The Wage-Productivity Trade Offs. *Journal of Urban Economics,* vol. 28**,** 140-159.

HANSON, G. H. (1996) Agglomeration, Dispersion, and the Pioneer Firm. *Journal of Urban Economics,* vol.39**,** 255-281.

HARRISON, W., JILL & PEARSON, K. R. (1994) *Computing Solutions for Large General Equilibrium Models Using GEMPACK,* Melbourne Centre of Policy Studies Monash University.

HARRISON, W. J. & PEARSON, K. R. (2002) An Introduction to GEMPACK (6th Edition). *GEMPACK Document No. GPD-1 (2nd Edition),* Monash University**,** 252 - 267.

HARRISON, W. J., PEARSON, K. R. & POWELL, A. A. (1996) Features of Multiregional and Intertemporal AGE Modelling with GEMPACK. *Computational Economics,* Vol 9**,** 331-353.

HAUGHWOUT, A. F. (1999) State Infrastructure and the Geography of Employment. *Growth and Change,* 30**,** 549 - 566.

HAYASHI, Y. & MORISUGI, H. (2000) International Comparison of Background Concept and Methodology of Transportation Project Appraisal. *Transport Policy,* 7**,** 73-88.

HAZEL, G. & PARRY, R. (2004) *Making Cities Work,* Great Britain, Wiley-Academy.

HEATHFIELD, D. F. & WIBE, S. (1987) *An Introduction to Cost and Production Functions,* Hong Kong, MacMillan Education Ltd.

HELSINKI CITY TRANSPORT (2009) Metropolitan Helsinki Commuter Rail Network Map, Timetables and Rolling Stock Information.

HENDERSON, V. (1986) Efficiency of Resource Usage and City Size. *Journal of Urban Economics,* vol. 19**,** 47-70.

HENDERSON, V. (2003) Marshall's Scale Economies. *Journal of Urban Economics,* Vol. 53**,** 1-28.

HIGGS, P., PARMENTER, B. R. & RIMMER, M. T. (1988) A Hybrid Top-Down, Bottom-Up, Regional Computable General Equilibrium Model. *International Science Review,* Vol. 11, No. 3**,** 317-328.

HLB DECISION ECONOMICS INC (2003) The Socio-Economic Benefits of Transit in Wisconsin - Final Report no: 0092-03-07. Wisconsin Department of Transportation.

HM TREASURY (2003) The Green Book - Appraisal and Evaluation in Central Government. IN TREASURY, H. (Ed., Treasury Guidance.

HOLTZ-EAKIN, D. (1993) New Federal Spending for Infrastructure : Should We Let This Genie Out of the Bottle ? . *Public Infrastructure Investment : A Bridge to Productivity Growth ? .* New York, The Jerome Levy Economics Institute Bard College.

HOLTZ-EAKIN, D. (1994) Public-Sector Capital and the Productivity Puzzle. *The Revew of Economics and Statistics,* 76 no 1**,** 12 -21.

HOOVER, E. M. (1937) *Location Theory and the Shoe and Leather Industries,* Cambridge, Massachusetts, Harvard University Press.

HOOVER, E. M. (1948) *The Location of Economic Activity,* New York, McGraw-Hill Book Company Inc.

HORRIDGE, J. M. (2003) *ORANI-G: A Generic Single-Country Computable General Equilibrium Model,* Melbourne, Centre of Policy Studies, Monash University.

HORRIDGE, J. M., MADDEN, J. & WITTWER, G. (2003) General Working Paper no. G-141: Using a Highly Disaggregated Multi-Regional Single-Country Model to Analyse the Impacts of the 2002 - 03 Drought on Australia. Melbourne, Centre of Policy Studies (Monash University).

HORRIDGE, J. M., MADDEN, J. R. & WITTWER, G. (2005) The Impact of the 2002 - 2003 Drought on Australia. *Journal of Policy Modeling* Vol 27**,** 285 - 308.

HORRIDGE, J. M., PARMENTER, B. R. & PEARSON, K. R. (1998) *ORANI-G: A General Equilibrium Model of the Australian Economy,* Melbourne, Centre of Policy Studies, Monash University.

HULTEN, C. & SCHWAB, R. (1991) Public Capital Formation and the Growth of Regional Manufacturing Industries. *National Tax Journal,* 44**,** 121-134.

INTERNATIONAL MONETARY FUND (2004) World Economic Outlook Database - 1995 PPP US Dollar Exchange Rate.

INTERNATIONAL MONETARY FUND (2010) IMF Exchange Rate Achive - Representation Exchange Rates for Selected Countries for June 1995.

JACOBS, J. (1969) *The Economy of Cities,* New York, Random House Inc.

JOHANSEN, L. (1972) *Production Functions,* Amsterdam, North-Holland Publishing Company.

JOHANSEN, L. (1974) *A Multisectoral Study of Economic Growth (2nd Edition),* Amsterdam, North-Holland.

JONES, R. & WHALLEY, J. (1989) A Canadian Regional General Equilibrium Model and Some Applications. *Journal of Urban Economics,* Vol. 25**,** 368 - 405.

KARATHODOROU, N., GRAHAM, D. & NOLAND, R. B. (2010) Estimating the Effect of Urban Density on Fuel Demand. *Energy Economics,* Vol. 32**,** 86-92.

KAWASHIMA, T. (1975) Urban Agglomeration Economies in Manufacturing Industries. *Paper of the Regional Science Association,* Vol. 34**,** 157-175.

KEEGAN, M., FAVERO, G. & PORTER, C. (2007) Transport Appraisal: Are we including all the benefits ? *UITP Magazine PT International,* Nov / Dec issue.

KELLEY, K. & MAXWELL, S. (2003) Sample Size for Multiple Regression: Obtaining Coefficients That Are Accurate, Not Simply Significant. *Psychological Methods,* Vol.8 no.3**,** 305-321.

KENWORTHY, J. & LAUBE, F. (1999a) *An International Sourcebook of Automobile Dependence In Cities 1960 - 1990,* Boulder, Colorado, University Press of Colorado.

KENWORTHY, J. & LAUBE, F. (1999b) Patterns of Automobile Dependence in Cities: An International Overview of Key Physical and Economic Dimensions with some Implications for Urban Policy. *Transportation Research Part A,* Vol 33**,** 691-723.

KIM, K. S. The Cost-Benefit Analysis Framework of the Republic of Korea. [online]. Message to: GWEE, E. [Accessed 9 January 2008]. Personal communication.

KLOOSTERMAN, R. C. & LAMBREGTS, B. (2001) Clustering of Economic Activities in Polycentric Urban Regions : The Case of the Ranstad. *Urban Studies,* vol 38 no. 4**,** 717 - 732.

LAM, A. The Cost-Benefit Analysis Framework of Hong Kong. [online]. Message to: GWEE, E. [Accessed 14 December 2007]. Personal communication.

LAND TRANSPORT AUTHORITY (1996) White Paper on A World Class Land Transport System IN LAND TRANSPORT AUTHORITY (SINGAPORE) (Ed.

LAND TRANSPORT NEW ZEALAND (2005) Economic Evaluation Manual (Vol 2). IN LAND TRANSPORT NEW ZEALAND (Ed.

LAND TRANSPORT NEW ZEALAND (2007) Economic Evaluation Manual (Vol 1) IN LAND TRANSPORT NEW ZEALAND (Ed.

LEE JR, D. B. (2000) Methods for Evaluation of Transportation Projects in USA. *Transport Policy,* 7**,** 41-50.

LIEW, L. H. (1981) A Multi-Regional Multi-Sectoral General Equilibrium Model of the Australian Economy. *Ph.D. Thesis* Melbourne, Monash University.

LIEW, L. H. (1984a) A Johansen Model for Regional Analysis. *Regional Science and Urban Analysis,* Vol. 14**,** 129-146.

LIEW, L. H. (1984b) "Tops-Down" Versus "Bottoms-Up" Approaches to Regional Modeling. *Journal of Policy Modeling,* Vol. 6 (3), 351-368.

LIM, W. L. The Cost - Benefit Analysis Framework of Singapore. [online]. Message to: GWEE, E. [Accessed 3 December 2007]. Personal communication.

LITMAN, T. (2004) Rail Transit in America : A Comprehensive Evaluation of Benefits. Victoria, Canada, American Public Transportation Association.

LITMAN, T. (2008a) Evaluating Accessibility for Transport Planning Victoria Transport Policy Institute.

LITMAN, T. (2008b) Transportation Elasticities - How Prices and Other Factors Affect Travel Behaviour. Victoria Transport Policy Institute.

LONGWORTH, T. (2008) Agglomeration Externalities: A Missing Piece of the Project Appraisal Puzzle? *Australian Transport Research Forum 2008.* Gold Coast, Australia.

LYNDE, C. & RICHMOND, J. (1992) The Role of Public Capital in Production. *The Revew of Economics and Statistics,* 74 no 1, 37 - 44.

LYNDE, C. & RICHMOND, J. (1993) Public Capital and Total Factor Productivity. *International Economic Review,* 34 no 2, 401 - 414.

MACKETT, R. L. (2001) Policies to Attract Drivers Out of Their Cars for Short Trips. *Transport Policy,* Vol 8, 295 - 306.

MADDEN, J. R. (1985a) Generating an Inter-Regional Input-Output Database for a Two-Region Model. *Paper presented to the 10th Meeting of the ANZ Regional Science Association.* University of Adelaide.

MADDEN, J. R. (1985b) A Proposal for Extending CREA's Regional General Equilibrium Model Capabilities. *Paper presented to the Macro-Econometric Models Workshop - Fourteen Conference of Economists.* University of New South Wales.

MADDEN, J. R. (1989) The Derivation of Coefficients and Parameters for the TASMAIN version of FEDERAL. *Working Paper No. TS-03.* Hobart, Centre for Regional Economic Analysis (University of Tasmania).

MADDEN, J. R. (1990) FEDERAL: A Two-Region Multi-Sectoral Fiscal Model of the Australian Economy. *Ph.D. Thesis.* Hobart, University of Tasmania.

MADDEN, J. R. (1993) The Economics of Vertical Fiscal Imbalance. *Australian Tax Forum,* Vol. 10, 75-90.

MADDEN, J. R. (2003) Assessing the Regional Economic Impact of an Airport: A Dynamic Multiregional CGE Study of Melbourne Airport. *50th Meeting of the North American Regional Science Association - 20-22 November* Philadelphia.

MADDEN, J. R. (2006) The Economic Effects of the Brisbane Airport Link. *Report prepared for Connell Wagner.* Melbourne, Centre of Policy Studies, Monash University.

MADDEN, J. R. (2008) The Economic Effects of Northern Link. *Report prepared for Connell Wagner.* Melbourne Centre of Policy Studies, Monash University.

MADDEN, J. R., CHALLEN, D. W. & HAGGER, A. J. (1983) The Grants Commission's Relativities Proposals: Effects on the State Economies. *Australian Economic Papers,* Vol. 22**,** 302 - 321.

MADDEN, J. R. & DIXON, P. B. (1990) The Economic Impact of the Very Fast Train. *Section C of The Economics of the Very Fast Train.* Canberra, VFT Joint Venture.

MADDEN, J. R. & GIESECKE, J. A. (1999) A Review of Two Decades of Large-Scale Multiregional CGE Modelling in Australia. *46th Meeting of the North American Regional Science Association (11-14 November 1999).* Montreal.

MADDEN, J. R., HAGGER, A. J. & PANT, H. M. (2008) The Impact on the Tasmanian Economy of Implementing the Recommendations of the Burton Committee. *Report for the Department of Transport* Hobart, Centre for Regional Economic Analysis, University of Tasmania.

MARSHALL, A. (1920) *Principles of Economics (8th Edition),* London, MacMillan & Co Ltd.

MARSHALL, A. & WEBBER, C. (2007) The Case for Better Transport Investment: Agglomeration and Growth in Leeds City Region. IN THE CENTRE FOR CITIES (LONDON) (Ed.

MCTAGGART, D., FINDLAY, C. & PARKIN, M. (2007) *Economics,* Frenchs Forest, NSW, Pearson Education Australia.

MEES, P. (2009) How Dense Are We? Another Look at Urban Density and Transport Patterns in Australia, Canada and the USA. *Proceedings of the State of Australian Cities National Conference (24 - 27 Nov 2009).* Perth.

MELBOURNE CITY COUNCIL (2003) Melbourne City Plan 2010. IN MELBOURNE CITY COUNCIL (Ed.

MELO, P. C., GRAHAM, D. & NOLAND, R. B. (2009) A Meta-Analysis of Estimates of Urban Agglomeration Economics *Regional Science and Urban Economics,* 39**,** 332-342.

MERA, K. (1973) Regional Production Functions and Social Overhead Capital : An Analysis of the Japanese Case. *Regional and Urban Economics,* vol 3 no 2**,** 157 - 186.

MERCER CONSULTING GROUP (2009) Mercer's Quality of Living Survey 2009.

METLINK (2008) Metropolitan Trains Time Tables.

METLINK (2009) Metropolitan Tram and Bus Timetables.

METROPOLITAN TRANSPORTATION AUTHORITY (2009a) New York City Subway Map and Timetables

METROPOLITAN TRANSPORTATION AUTHORITY. Rolling Stock Information. [online]. Message to: GWEE, E. [Accessed 21 Sept 2009]. Personal communication.

MINDALI, O., RAVEH, A. & SALOMON, L. (2004) Urban Density and Energy Consumption: A New Look at Old Statistics. *Transportation Research Part A,* Vol 38**,** 143 - 162.

MIYAGI, T. (1998) A Spatial Computable General Equilibrium Approach for Measuring Multiregional Impacts of Large Scale Transportation Projects. IN LUNDQVIST, L., MATTSSON, L.-G. & KIM, T. J. (Eds.) *Network Infrastructure and the Urban Environment - Advances in Spatial Systems Modelling.* Heidelberg, Springer.

MIYAGI, T. (2001) Economic Appraisal for Multi-Regional Impacts by a Large Scale Expressway Project - Tinbergen Institute Discussion Paper TI2001-066/3. IN TINBERGEN INSTITUTE (Ed.

MONOCLE (2009) Monocle's Most Livable Cities Index 2009.

MOOMAW, R. L. (1983) Is Population Scale a Worthless Surrogate for Business Agglomeration Economies ? . *Regional Science and Urban Economics,* 13**,** 525-545.

MORISUGI, H. (2000) Evaluation Methodologies of Transportation Projects in Japan. *Transport Policy,* 7**,** 35-40.

MTR (2009) Hong Kong Commuter Rail Network Map, Timetables and Rolling Stock Information.

MUNNELL, A. H. (1990a) How Does Public Infrastructure Affect Regional Economic Performance ? *New England Economic Review - Federal Reserve Bank of Boston,* Sep / Oct 11-33.

MUNNELL, A. H. (1990b) Why Has Productivity Growth Declined ? Productivity and Public Investment. *New England Economic Review - Federal Reserve Bank of Boston,* Jan / Feb 3-22.

MVV (2009) Metropolitan Munich Commuter Rail Map and Timetables.

NAKAMURA, H. (2000) The Economic Evaluation of Transport Infrastructure: Need for International Comparison. *Transport Policy,* 7**,** 3-6.

NAKAMURA, R. (1985) Agglomeration Economies in Urban Manufacturing Industries: A Case of Japanese Cities. *Journal of Urban Economics,* Vol. 17 no. 1**,** 108-124.

NAPPER, R. (2007) Route Bus Transport - Stakeholders, Vehicles and New Design Directions. *29th Conference of Australian Institute of Transport Research.* Adelaide.

NAQVI, F. & PETER, M. (1996) A Multiregional, Multisectoral Model of the Australian Economy with an Illustrative Application. *Australian Economic Papers,* 35**,** 94-113.

NASH, C. (1992) Appraisal of Rail Projects. *Project Appraisal,* 7, no. 4**,** 211-218.

NASH, C. & PRESTON, J. (1991) Appraisal of rail investment projects : recent British experience. *Transport Reviews,* 11, no.4**,** 295 -309.

NEUMAN, W. L. (1991) *Social Research Methods - Qualitative and Quantitative Approaches (3rd Ed),* USA, Allyn and Bacon.

NEW ZEALAND TRANSPORT AGENCY (2008) Economic Evaluation Manual (Volume 1) - Amendment No. 2 version.

NEWMAN, P. & KENWORTHY, J. (1989) *Cities and Automobile Dependence: A Sourcebook,* Aldershot, Gower Publishing Company Limited.

O'HUALLACHAIN, B. & LESLIE, T. (2007) Producer Services in the Urban Core and Suburbs of Phoenix, Arizona. *Urban Studies,* Vol 44 no. 8**,** 1581-1601.

OOSTERHAVEN, J. & ELHORST, J. (2003) Indirect Economic Benefits of Transport Infrastructure Investments. *Across the Border: Building on a Quarter Century of Transport Research in the Benelux.* Antwerp, De Boeck.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) (2002) Glossary of Statistical Terms - International Trade Statistics.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) (2010) OECD.Stat Extracts - PPPs and Exchange Rates (1995).

ORTUZAR, J. & WILLUMSEN, L. G. (2001) *Modelling Transport,* New York, John Wiley.

OTTAVIANO, G., TABUCHI, T. & THISSE, J.-F. (2002) Agglomeration and Trade Revisited. *International Economic Review,* Vol. 43 no. 2**,** 409 - 435.

PALLANT, J. (2005) *SPSS Survival Manual - a step by step guide to Data Analysis using SPSS (2nd Edition),* Sydney, Allen & Unwin.

PARSONS BRINCKERHOFF QUADE & DOUGLAS INC (1998) Land Use Impacts of Transportation : A Guidebook (Project 8-32(3) Integration of Land Use Planning with Multimodal Transportation Planning. *National Cooperative Highway Research Program.* Transportation Research Board.

PATMORE, J. A. (1966) The Contraction of the Network of Railway Passenger Services in England and Wales, 1836 - 1962. *Transactions of the Institute of British Geographers,* Vol 38**,** 105-118.

PHELPS, N. A. (2004) Clusters, Dispersion and the Spaces in Between: For an Economic Geography of the Banal. *Urban Studies,* vol 41 no 5/6**,** 971 - 989.

PORTER, M. (1990) *The Competitive Advantage of Nations,* New York, The Free Press.

POWELL, A. A. & SNAPE, R. H. (1993) The Contribution of Applied General Equilibrium Analysis to Policy Reform in Australia. *Journal of Policy Modeling,* Vol 15**,** 393 - 414.

PRICEWATERHOUSECOOPERS (2008) Review of the Estimation of Wider Economic Benefits - East West Projects Economic Analysis. Melbourne, Department of Premier and Cabinet (Victoria).

PRICEWATERHOUSECOOPERS (2009) UK Economic Outlook. United Kingdom.

PRUD'HOMME, R. & LEE, C.-W. (1999) Size, Sprawl, Speed and the Efficiency of Cities. *Urban Studies,* vol 36 no 11**,** 1849 - 1858.

PUBLIC TRANSPORT DIVISION (2008) East West Rail Link - Analysis of Rail Capacity. IN DEPARTMENT OF INFRASTRUCTURE (VICTORIA) (Ed.

QUINET, E. (2000) Evaluation Methodologies of Transportation Projects in France. *Transport Policy,* 7**,** 27-34.

RHEINBAHN (2009) Metropolitan Dusseldorf Commuter Rail Network Map, Timetables and Rolling Stock Information.

RICE, P., VENABLES, A. J. & PATACCHINI, E. (2006) Spatial Determinants of Productivity: Analysis for the Regions of Great Britain. *Regional Science and Urban Economics,* 36**,** 727-752.

RICHARDSON, A. J., AMPT, E. S. & MEYBURG, A. H. (1995) *Survey Methods for Transport Planning,* Melbourne, Australia, Agency Printing (Aust) Pty. Ltd.

ROSENTHAL, S. & STRANGE, W. (2001) The Determinants of Agglomeration. *Journal of Urban Economics,* Vol 50**,** 191-229.

ROSENTHAL, S. & STRANGE, W. (2004) Evidence on the Nature and Sources of Agglomeration Economies. IN HENDERSON, V. & THISSE, J.-F. (Eds.) *Handbook of Regional and Urban Economics Volume 4 - Cities and Geography.* Elsevier North Holland.

ROTHENGATTER, W. (2000) Evaluation of Infrastructure Investments in Germany. *Transport Policy,* 7**,** 17-25.

SAXENIAN, A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* Cambridge, MA, Harvard University Press.

SEGAL, D. (1976) Are There Returns To Scale in City Size? *The Revew of Economics and Statistics,* Vol. 58 no. 3**,** 339-350.

SEITZ, H. (1995) The Productivity and Supply of Urban Infrastructures. *The Annals of Regional Science,* 29**,** 121 - 141.

SEITZ, H. & LICHT, G. (1995) The Impact of Public Infrastructure Capital on Regional Manufacturing Production Cost. *Regional Studies,* vol.29 no.3 231 - 240.

SERVICE SKILLS VICTORIA (2007) Industry Change Drivers Report (2006 Service Qualitative Data). IN SERVICE SKILLS VICTORIA (Ed.

SGS ECONOMICS AND PLANNING PTY LTD (2008) Melbourne Employment Projections - Final Report. Melbourne Victorian Department of Transport.

SHEFER, D. (1973) Localization Economies in SMSA's: A Production Function Analysis. *Journal of Regional Science,* Vol.13 no.1**,** 55 - 63.

SIMMIE, J. (2004) Innovation and Clustering in the Globalised International Economy. *Urban Studies,* vol 41 no 5/6**,** 1095 - 1112.

SINCLAIR KNIGHT MERZ (1998) Scoresby Transport Corridor Environment Effects Statement (main report - vol 1). Melbourne, Australia, Department of Infrastructure and VicRoads.

SMRT. Rolling Stock Information of Singapore SMRT. [online]. Message to: GWEE, E. [Accessed!st Sept 2009]. Personal communication.

SMRT (2009b) Singapore Rapid Transit Network Map and Timetables.

SOCIO-ECONOMIC & ENVIRONMENTAL RESEARCH INSTITUTE (2008) Total Factor Productivity - What is it ? . *Penang Economic Monthly,* vol 10 issue 2**,** 1-6.

SOUCHE, S. (2010) Measuring the Structural Determinants of Urban Travel Demand. *Transport Policy,* Vol. 17 no. 3**,** 127 - 134.

STANDARD AND POOR'S (2003) Victoria's 'AAA' Rating: A Comparative Study of Financial and Economic Performance. Melbourne.

STATE OF WISCONSIN (2008) Information about the State of Wisconsin (USA).

STIB (2009) Metropolian Brussels Commuter Rail Network Map, Timetables and Rolling Stock Information

STONE, R. (1954) Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. *The Economic Journal,* Vol 64. No. 255**,** 511-527.

STRAUSS-KAHN, V. & VIVES, X. (2009) Why and Where do Headquarters Move? *Regional Science and Urban Economics,* vol 39**,** 168-186.

SVEIKAUSKAS, L. (1975) The Productivity of Cities. *The Quarterly Journal of Economics,* Vol.89 no.3**,** 393-413.

SVEIKAUSKAS, L., GOWDY, J. & FUNK, M. (1988) Urban Productivity: City Size or Industry Size. *Journal of Regional Science,* vol. 28 no. 2**,** 185-202.

SWISS FEDERAL RAILWAYS (2009) Commuter Rail Network Map and Timetables Information for Metropolitan Stockholm.

TABUCHI, T. (1986) Urban Agglomeration, Capital Augmenting Technology, and Labour Market Equilibrium. *Journal of Urban Economics,* Vol. 20 no. 2**,** 211-228.

TAYLOR, Z. (2006) Railway Closures to Passenger Traffic in Poland and their Social Consequences. *Journal of Transport Geography,* Vol 14**,** 135-151.

TELSTRA COOPERATION LIMITED (2009) Australian Yellow Pages

THE ECONOMIST INTELLIGENCE UNIT (2009) The Economist's World's Most Livable Cities 2009.

TOEI SUBWAY (2009) Metropolitan Tokyo Subway Network and Timetables, .

TOKYO METRO (2009) Metropolitan Tokyo Metro Network and Timetables, .

TRANSADELAIDE. Adelaide Train Configuration and Carrying Capacity for AM Peak. [online]. Message to: GWEE, E. 10 July 2009. [Accessed Personal communication.

TRANSADELAIDE (2009b) Adelaide Train Network and Timetables. Adelaide.

TRANSIT TORONTO (2008) Carrying Capacity of Rolling Stock Series H1, H2, H3 and H4. Transit Toronto.

TRANSLINK (2009) Metropolitan Vancouver Commuter Rail Network Map and Timetables.

TRANSPERTH. Carrying Capacity of Transperth Rolling Stock. [online]. Message to: GWEE, E. 29 July 2009. [Accessed Personal communication.

TRANSPERTH (2009b) Perth Train Network and Time Tables.

TRANSPORT CANADA (1994) Guide to Benefit-Cost Analysis in Transport Canada. IN TRANSPORT CANADA (Ed.

TRANSPORT DATA CENTRE (2008) Transfigure - Employment and Commuting in Sydney's Centres, 1996 - 2006 - December 2008 issue Sydney, Ministry of Transport (NSW).

TRANSPORT DATA CENTRE. CBD Work-Related Trips in AM Peak. [online]. Message to: GWEE, E. [Accessed 9 Nov 2009]. Personal communication.

TRANSPORT DATA CENTRE. The Size of Sydney CBD - information from Transport Data Centre. [online]. Message to: GWEE, E. [Accessed 16 Sept 2009]. Personal communication.

TRANSPORT FOR LONDON (2006) London Top for Public Transport. *Transport for London News,* Issue 14 - autumn Page 8.

TRANSPORT FOR LONDON (2009) Metropolitan London Tube Map, Timetables and Carrying Capacity of Rolling Stock for Various Lines.

TRANSPORT RESEARCH CENTRE (1999) Victorian Activity and Travel Survey (1994 - 1999).

TRANSPORTATION RESEARCH BOARD (1996) TCRP Report 20 - Measuring and Valuing Transit Benefits and Disbenefits. *Transit Cooperative Research Program.* Washington, D.C., Transportation Research Board, National Research Council.

TRANSPORTATION RESEARCH BOARD (1998) TCRP Report 35 - Economic Impact Analysis of Transit Investments: Guidebook for Practitioners. *Transit Cooperative Research Program.* Washington, D.C., Transportation Research Board, National Research Council.

TRANSPORTATION RESEARCH BOARD (2002) TCRP Report 78 - Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners. *Transit Cooperative Research Program.* Washington D.C., Transportation Research Board - National Research Council.

TRANSPORTATION RESEARCH BOARD (2004) TCRP Report 95 (Chapter 12) - Transit Pricing and Fares (Traveller Response to Transportation System Changes) *Transit Cooperative Research Program.* Washington DC, Transportation Research Board.

TREASURY BOARD OF CANADA SECRETARIAT (1998) Benefit-Cost Analysis Guide. IN TREASURY BOARD OF CANADA SECRETARIAT (Ed.

UITP INSTITUTE FOR SUSTAINABILITY AND TECHNOLOGY POLICY (2001) Millennium Cities Database.

US DEPARTMENT OF STATE (2008) International Information Programs.

VAN DE COEVERING, P. & SCHWANEN, T. (2006) Re-evaluating the Impact of Urban Form on Travel Patterns in Europe and North-America. *Transport Policy,* Vol. 13**,** 229 - 239.

VAN DER HOORN, T. Cost-Benefit Analysis Practice in the Netherlands. [online]. Message to: GWEE, E. [Accessed 2 January 2008]. Personal communication.

VENABLES, A. J. (2004) Evaluating Urban Transport Improvements : Cost-Benefit Analysis in the Presence of Agglomeration and Income Taxation. London, London School of Economics and CEPR : DfT.

VENABLES, A. J. (2007) Evaluating Urban Transport Improvements: Cost Benefit Analysis in the Presence of Agglomeration and Income Taxation. *Journal of Transport Economics and Policy,* Vol. 41 (2)**,** 173 - 188.

VENABLES, A. J. & RICE, P. (2004) Spatial determinants of productivity: analysis for the UK regions. *Working paper for the Evidence Based Policy Fund project "Regional inequalilites in the UK: productivity, earnings and skills"*.

VGF (2009) Metropolitan Frankfurt Commuter Rail Network Map and Timetables.

VICKERMAN, R. (2000) Evaluation Methodologies for Transport Projects in the United Kingdom. *Transport Policy,* 7**,** 7-16.

VICKERMAN, R. (2007a) Provision of Public Transport Under Conflicting Regulatory Regimes. *10th International Conference on Competition and Ownership in Land Passenger Transport* Hamilton Island, Australia.

VICKERMAN, R. (2007b) Research Round Table: Recent Evolution of Research into the Wider Economic Benefits of Transport Infrastructure Investments. *European Conference of Ministers of Transport - Joint OECD / ECMT Transport Research Centre*.

VICKERMAN, R. (2008a) Cost-Benefit Analysis and the Wider Economic Benefits from Mega-Projects. IN PRIEMUS, H., FLYVBJERG, B. & WEE, B. V. (Eds.) *Decision-Making on Mega-Projects - Cost-Benefit Analysis, Planning and Innovation.* Cheltenham UK, Edward Elgar.

VICKERMAN, R. (2008b) Provision of Public Transport Under Conflicting Regulatory Regimes. *Transportation Research Part A,* Vol. 42**,** 1176 - 1182.

VICROADS (2008a) Journey to Works (1996 - 2006): Census Statistics for Origin / Destination of Journeys to Work, Method of Travel and Mode Share for Victorian Geographies. Melbourne.

VICROADS. Registered Vehicle Population for State of Victoria. [online]. Message to: GWEE, E. [Accessed 20 June 2008]. Personal communication.

VIVIER, J. (2001) Millennium Cities Database for Sustainable Mobility - Analyses and Recommendations.

VIVIER, J. New Development regarding Millennium Cities Database. [online]. Message to: GWEE, E. [Accessed Personal communication.

WEGMANN, F. J., CHATTERJEE, A., PARNELL, S. & WELCH, G. L. (1979) Impact of the 1977 Transit Strike in Knoxville. *Transportation Research Record 719***,** 6 - 13.

WIENER LINEIN (2009) Metropolitan Vienna Commuter Rail Network Map and Timetables.

WIGLE, R. M. (1992) Transportation Costs in Regional Models of Foreign Trade: An Application to Canada - U.S. Trade. *Journal of Regional Science,* Vol. 32**,** 185 - 207.

WIKIPEDIA (2009) Information on the Rolling Stock for the Urban / Suburban Passenger Train Systems of Hong Kong, Singapore, Munich, Vancouver, Copenhagen, Stockholm, Zurich, Geneva, Helsinki, Tokyo, New York and Paris. Wikimedia Foundation Inc.

WILLIAMSON, S. D. (2002) *Macroeconomics,* Boston, Addison Wesley.

WISCONSIN DEPARTMENT OF TRANSPORTATION (2008) Transportation Fact Sheet of State of Wisconsin.

WITTWER, G. & HORRIDGE, M. (2010) Bringing Regional Detail to a CGE Model using Census Data. *Spatial Economic Analysis,* Vol.5 (2)**,** 230 - 255.

WOLMAR, C. (2004) *Subterranean Railway: how the London undersground was built and how it changed the city forever,* London, Alantic Books.

YOUNG, L. (2002) Determining the Discount Rate for Government Projects. *Working Paper 02/21.* Wellington, New Zealand Treasury.

YOUNG, W. (2005) A Review of Land Use / Transport / Environmental Interaction Models. *Australian Research Council's Key Centre Program.* Melbourne, Institute of Transport Studies Monash University.

ZWARTJES, S. The Cost Benefit Appraisal Framework of the Netherlands. [online]. Message to: GWEE, E. [Accessed 12 December 2007]. Personal communication.