MONASH UNIVERSITY

FACULTY OF BUSINESS & ECONOMICS

A COMPARISON OF ROBOT TECHNOLOGY MANAGEMENT IN TWO COUNTRIES

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Abstract

This paper compares a recent study of robot technology management in the Australian manufacturing industry with a similar study conducted in Spain. The key areas of comparison include:

- Benefits derived from robots.
- Perceived shortcomings of the technology.
- Payback periods experienced.
- Relationship between the size of the organisation and level of benefit achieved.
- Worker's attitudes before the installation of robots.
- Intention to make further investments in the technology.

The findings of the two studies are compared to determine the impact of the different manufacturing environments of the two countries on the experiences of the local organisations with the adoption of robot manufacturing technology. Some of the findings common to both studies were that benefits of robot technology included product quality and production flexibility, that attitudes toward the installations before installation were positive, that the majority of companies would acquire more robots in the future and that supplier involvement and project planning were important components of the effective management of robot manufacturing systems. Both surveys also found that the efficient use of the technology was effected by limitations in the capacity of the technology itself and the organisation's level of experience with the technology. The findings of the two studies agreed on the most important dimensions of technology adoption which includes: uses of the technology, performance, shortcomings and benefits, worker responses and financial returns. This suggests that the management of robot manufacturing technology has a set of common functional similarities which is independent of the manufacturing environments.

Keywords: Robots, Advanced Manufacturing Technology, Technology Management.

INTRODUCTION

Industrial robots are used in all industrialised nations. As indicated in Table 1, their utilisation has generally increased over the last 16 years, although some countries, such as Japan are reducing their rates of robot installation in favour of other methods of increasing manufacturing competency, such as manufacturing process streamlining. The nature and focus of this technology is changing in many countries, which may indicate that this technology has reached a significant point in its evolution. For example, industrial robot manufacturers in Japan have recently been directing marketing efforts toward small and medium-sized firms, rather than large users which are the traditional customers [1]. Two main factors have prompted this shift of market emphasis:

1. Traditional demand is no longer very high as 80 - 90% of large firms have now integrated robots into their production processes.

2. There is a reduction of plant and equipment acquisition as firms have adjusted for lower profits caused by the economic slowdown in Japan and its major trading partners.

3. The demand for automation in Japan has reduced because many major Japanese manufacturers have increased their outsourcing of labour intensive activities, which are traditional targets for automation, to low cost offshore sites.

Table I: Robots Installed in Australia and Spain.

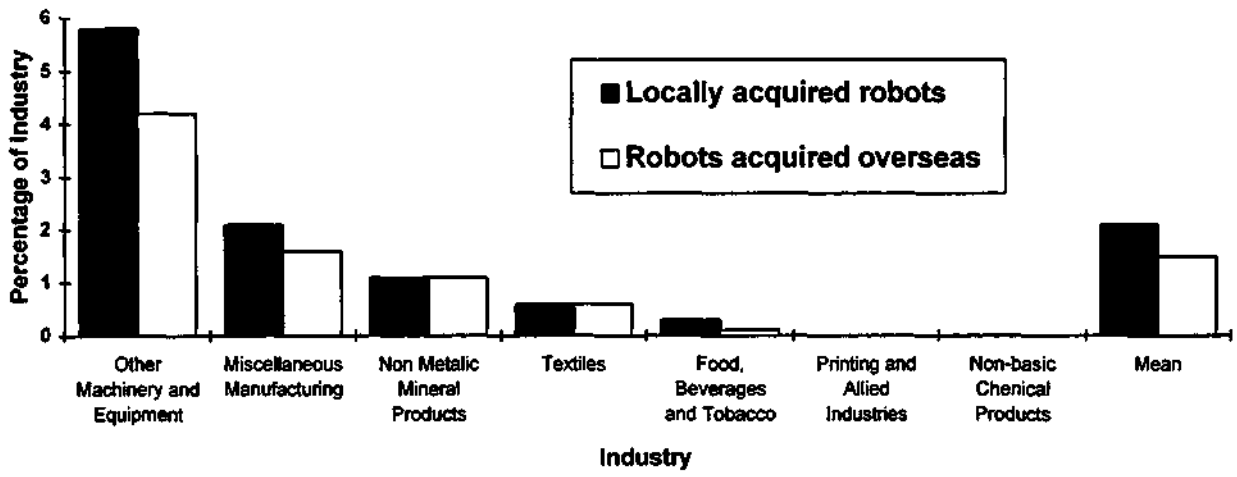
Year	Australia	Spain	USA	Western Europe	Japan
1980	140	-	4500	3200	14000
1986	800	-	25000	20100	93000
1990	1490	1302	40000	74500	274000
1993	1900	*	*	*	*
Average rate of increase per annum	24%		22%	33%	31%

* 1993 figures were not available at the time of preparing this paper.

By contrast, Mittelstadt suggested that automation (long been viewed as a luxury by many US manufacturers), is essential to maintaining manufacturing competitiveness in a worldwide market [2]. He claimed that US manufacturers did not use robots as frequently and productively as the Japanese and European manufacturing industries. In Europe, government and industry invest $ US 1.5 million million per year in industrial robot systems [2]. The Swedish manufacturing industry, for example, is a substantial user of automated manufacturing. In the 1970s, Swedish industry foresaw a growing shortage of skilled labour as well as changes in work ethics which would reduce labour productivity. It elected to automate its factories and, by 1990, had installed 25,000 industrial robots [3], compared with 40,000 in all of North America, as shown in Table 1. The fall in Sweden's export/import ratio in more recent years [4] indicates that a proactive automation policy is not sufficient to ensure economic success and that other advanced manufacturing and service approaches such as quality management and best practice must also be adopted.

In 1989 the Australian Bureau of Statistics (ABS) released a survey of AMTs [5]. This was the first ABS survey of this type and provided some quantitative data of the extent of the adoption of AMTs and particularly robots, in the Australian manufacturing industry. The survey included manufacturers with 10 or more employees. Figure 1 shows the number of Australian manufacturers that applied this technology as well as whether the technology was sourced in Australia or overseas. The majority of robot systems surveyed by the ABS were originally sourced from overseas rather than from Australian suppliers. It also shows that the adoption of robots across the 15,976 manufacturers operating in Australia at the time was below 5%. A more detailed analysis shows that large manufacturing establishments (with more than 200 employees) had greater proportions of robots (up to 15%), medium sized establishments (50 - 199 employees) had the same proportion of robots as the industry mean and small establishments (10 - 49 employees) had the lowest levels of adoption of robot technology, typically below 2%. Small manufacturers represented the majority of Australian manufacturing establishments; at the time there were 11,917 small establishments registered in Australia.

Figure 1: Diffusion of robots into industry



Several major inquiries into the Australian manufacturing industry identified the need for industry to be more outward-looking, more competitive internationally and more innovative in product and process development. Manufacturers in Australia are suffering intense competitive pressure from other countries and will not prosper unless they respond to the challenge to improve product quality and reliability and reduce production costs [6]. If Australian manufacturers wish to compete globally, against lower labour costs and other such barriers, then they must consider automation or move production to locations where labour costs are comparable [7]. Achieving this level of manufacturing competency will require producers to address the issue of the trade-offs between efficiency and flexibility [8]. However, cost efficient flexibility can be achieved in many industries by adopting advanced manufacturing technologies, such as industrial robots [8]. The lower production levels in countries such as Australia and Spain make robots an appropriate automation technology [9].

Unfortunately, many studies have shown that Australian manufacturers' successes with advanced manufacturing technologies (AMTs), and particularly robots, has been mixed [8, 9, 10, 11]. The

Australian Chamber of Manufactures stated in a report on their national strategy to develop the Australian manufacturing industry [4] that "manufacturing enterprises have a responsibility to be forward-thinking in investment decisions, sensitive in managing human and physical resources, efficient in the safe, timely production of high quality globally competitive products and aggressive in creating new export markets and opportunities." An assessment of all manufacturing industries in five countries (including Australia) identified a number of differences between Australia's manufacturing performance and some of the more successful industrialised countries [4]. All countries demonstrated an increase in value-added per employee, however, the value-added per employee in Australia is the lowest of any of these countries and is clearly an area for improvement. Australia's export versus import ratio is improving (Sweden and Japan are worsening), however, as is its value-added per employee. The low value-added per employee suggests inefficient work practices in Australia and a lack of adoption of efficient manufacturing processes, which includes AMTs, such as robots.

Table 1 indicates that the adoption of this technology in Australia (1,900 units for a population of 17 million or 112 robots per million inhabitants) does not compare favourably with the situation in Japan (274,000 units for a population of 124 million inhabitants or 2,210 robots per million inhabitants) in 1990. This table suggests that, for a country to maintain a competitive manufacturing industry it must strongly consider the utilisation of AMTs such as industrial robots to increase manufacturing competitiveness. AMT adoption alone is not sufficient to ensure manufacturing competitiveness, as Japan's worsening export to import rations demonstrates [4], however, studies have shown that it is a contributing factor [9, 11, 12, 13]. Many Australian manufacturers have no AMT adoption strategies and have not seriously evaluated the benefits of AMTs [11]. This observation would probably apply to many other industrialised countries as well.

These issues are important and must be evaluated by all manufacturing industries. This paper presents the findings of a research project that compares the success of robot technology adoption and its management in Australia and Spain. The objective is to evaluate the effectiveness of robot technology utilisation in these two countries.

A survey of robot usage in Spain which will be referred to in detail in the findings section of this paper identified some important findings in relation to robot usage [14]:

1. Firms introducing industrial robots had usually had some experience with automation prior to making the decision to acquire industrial robots.

2. The implementation of industrial robots proved to be a learning experience which is useful in the implementation of other AMTs (such as computer aided manufacturing).

3. Personnel training is a widespread practice in firms which have introduced robots.

4. The higher the firm's level of training and technology, the faster it will recoup its investment in robot technology.

5. Feasibility studies should include all organisational and technical features of the robot's environment, as the majority of reasons for low levels of productivity proved to be associated with ancillary equipment.

6. Suppliers should be chosen on the basis of technical capacity.

7. Worker opposition to the introduction of industrial robots is reduced when those who are affected are consulted or brought into the decision making process prior to the acquisition of this technology.

8. Support from top management for robot projects proved to be greater in the small organisations than in the large organisations. There was a direct correlation between the level of support for the project and the payback period.

METHODOLOGY

The Australian data were collected from the second stage of a project which started in 1990 with a survey of users or companies involved with industrial robots in Australia [15]. The findings of the 1990 survey were used to prepare a set of detailed case studies and a report. This survey was conducted using an interview guide derived from past AMT questionnaires, including that used by Sohal, Samson, and Ramsay [12]. A second survey was conducted in 1993, using the same questions used as in the 1990 interview guide. This time, however, a postal questionnaire was used to include as many users as possible in a national survey. Fifty-eight organisations responded, out of 112 identified robot users, resulting in a response rate of 52%. The postal survey is included in Appendix A. A follow-up letter and telephone call were also used to maximise the response rate. The smallest company included in this survey employed 10 staff whilst the largest company surveyed employed approximately 10,000 staff. Organisations surveyed came from industries such as general manufacturing, transport and automotive components, electronics, communications and plastics moulding.

The objectives were to determine:

1. Whether the expectations of management were being meet by robot technology.

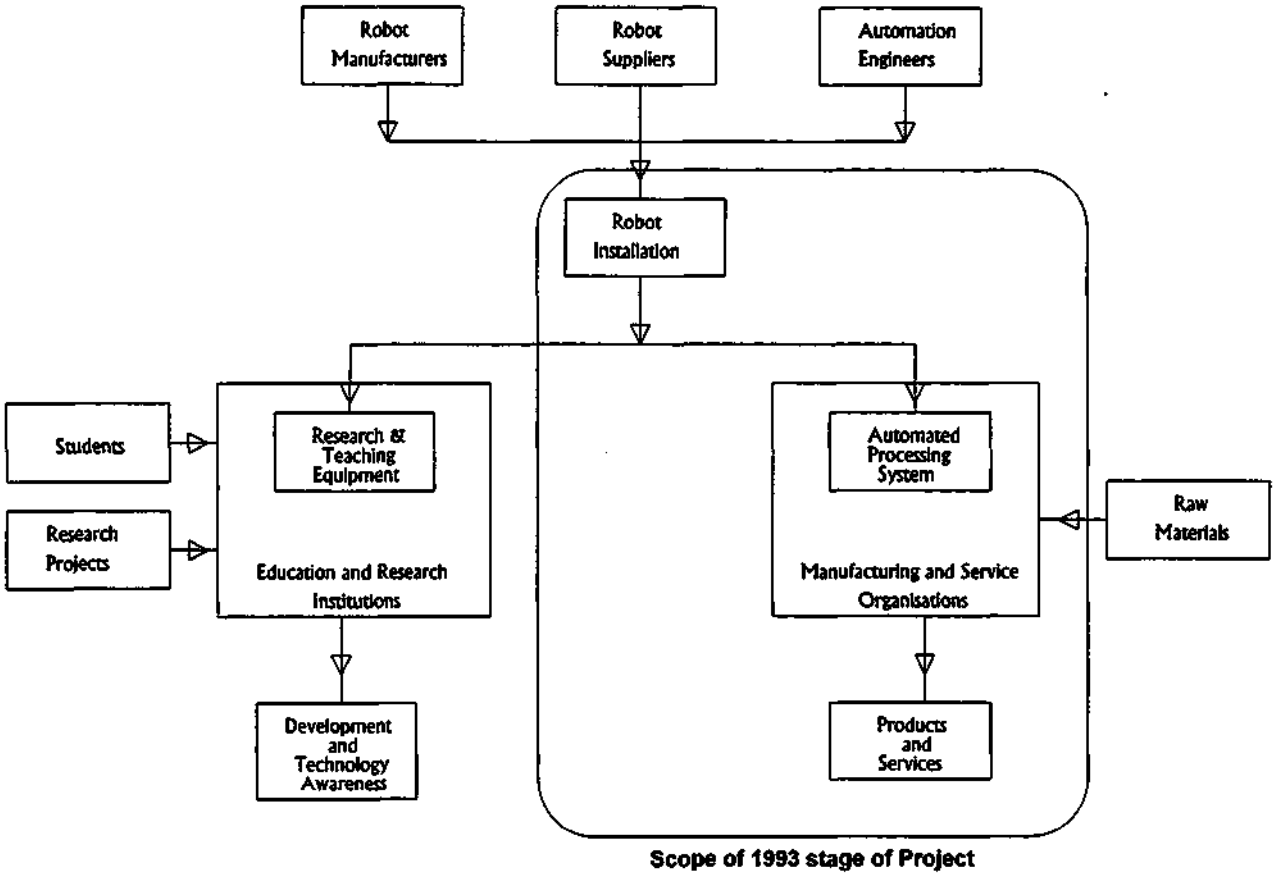
2. The impact of robot manufacturing technology on the workforce.

3. The strengths and weaknesses of the technology under manufacturing conditions.

4. The likely future impact of the technology on the Australian manufacturing industry.

Figure 2 shows that the scope of the 1993 survey concentrates on manufacturing and service organisations.

Figure 2: Structure of the Australian robot industry.



The Spanish survey was conducted in 1992 using a mail questionnaire, followed by personal interviews with technical managers. The response rate for the Spanish research was 26%, which corresponded to 44 out of the 172 robot users identified [14]. Thus the data collection methodologies and survey conditions make these two studies very comparable.

Analysis of Survey Results

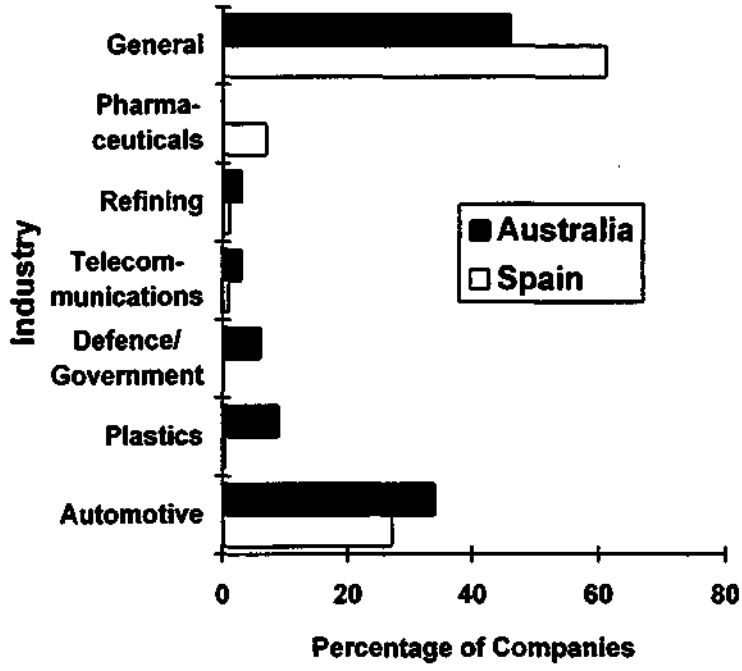
The following discussion compares the findings of the Spanish and Australian surveys.

Which production activities do you use robots for?

Figure 3 shows the percentage of companies for each of the industry categories in which the respondents used their robots. In most cases, this was identical to the industry in which the company operated, however, in some cases, the company operated in several different industries. In Australia, the highest rate of usage of robots was for General Manufacturing (46%) and the next highest for the Automotive industry (34%). All other industries recorded low levels of usage, ranging from 3% to 9%. The Spanish survey also found that robots were also primarily used for the General manufacturing industry (61%) and the Automotive industry (27%). The similarity of these two findings suggests that the same industries are the principal robot users in all industrialised countries. In many cases manufacturers in these industries would use robots for simple applications, although the Australian survey did not identify a significant difference in the technical capacities of the robots used in the industries surveyed. Although the applications of robots might

be simpler in some cases, this should not make the amalgamation of the data from all respondents inappropriate.

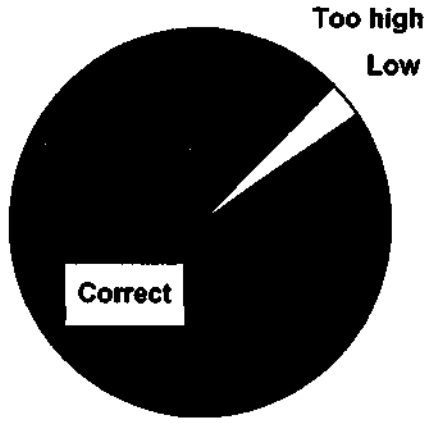
Figure 3: Production activities in which robots were used.



How did your initial expectations rate against your experiences after installing robots?

Figure 4 rates the correlation of initial expectations of management against the post installation experiences. In the Australian study, the majority of the managers' expectations were correctly met, with only 8% being disappointed with the outcome. These findings support the increase in positive attitudes toward robots in Australia after their installation. The Spanish industry found that they had more breakdowns, and less operating hours than predicted after installation, but that the payback periods experienced were shorter than forecast. This and the fact that most of the Spanish organisations had also had experience with non-robot automation before installing the robots suggests a positive view of robots before installation, which was maintained after installation. The access which Spain has to the European Union market would increase the accuracy of market forecasts and dependability of sales volumes and would therefore increase the likelihood of success of capital investments, such as robot installations, the success of which is dependent on forecast production volumes.

Figure 4: Initial expectations rated against experiences after installing robots for Australian companies.



Gold [16] found that, when evaluating new technologies, managers:

- Underestimated the time needed for effective utilisation.
- Overestimated the gains in efficiency expected.
- Did not consider the costs of gaining labour acceptance of major innovations.
- Assumed that the company would convert all reduction in unit costs to profits.

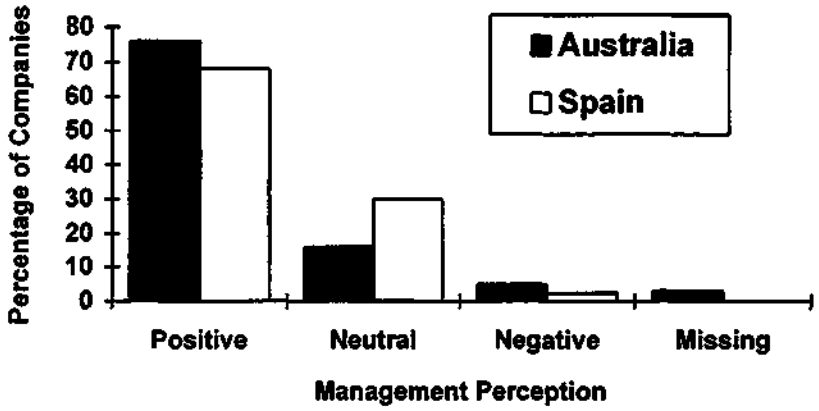
This obviously does not occur in relation to the adoption of robot technology, perhaps because of the level of financial scrutiny the projects are exposed to in both countries. In the Spanish companies, 80% of the final decisions were made by the Company Board of Directors, with 75% of the companies conducting a feasibility survey prior to purchase. The majority (54%) of the Australian companies found some difficulty in justifying their robot installation project and only 29% encountered low resistance to their robot installation proposals. These findings suggest senior management is now closely scrutinising capital investment in technology such as robots. Such technologies must be able to stand on their own in regard to return on investment.

What were the workers' responses to automation?

Figure 5 shows management's perceptions of the attitudes of workers toward automation in their organisation. Australian Management believed that the majority (78%) of workers had a positive attitude toward automation. The Spanish industry study found that the most common perceived worker response before installation was neutral (42%) and, after installation was favourable (68%). The earlier lack of appreciation of the impact of complex technologies may explain why there was a shift in attitude toward automation after installation - as workers become more certain of their views. A greater understanding of the impact of this technology might have influenced the expectations of the workers. In both cases, the surveys only addressed the management perceptions of employee responses to automation. The successful installation of AMTs such as robots requires the support and appreciation of the process workers [3, 10, 17, 18] and as the majority of the

instillations did appear to be successful (see 'benefits' and 'payback period' discussions following), it is likely that the managers did have the opportunity to gain a true appreciation of the process worker's perspectives. This finding should, however, be treated with caution, as it is based on perceptions only.

Figure 5: Workers' responses to automation.



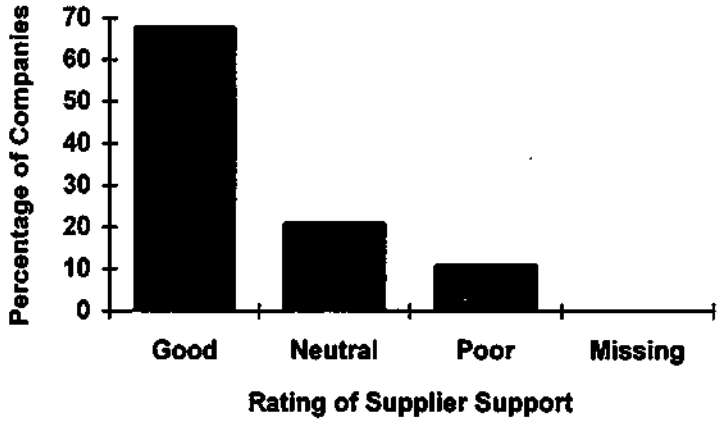
Do you hold advance discussions with workers prior to automating?

The Spanish industry study showed that 85% of the organisations had informed and consulted with the people affected by the automation, or had involved them in working groups. The Australian survey shows that the majority (83%) of organisations did hold advance discussions with workers regarding future automation plans. The results for the other questions of "worker responses to automation" and "policy of no retrenchment through automation" also showed a positive attitude toward consideration of workers and worker involvement. It could be concluded, therefore, that the Australian organisations which hold advance discussions with workers and have a policy of no retrenchments through automation develop a positive organisational attitudes toward automation. Weill, Samson, and Sohal [10] suggested that the introduction of robots will ultimately result in a higher skilled and remunerated workforce. The respondents of both the Australian and Spanish surveys did not indicate whether this had occurred. Orr [15] found that the impact on the workforce and structure of the organisation occurred very slowly and was consequently difficult to measure.

What was the quality of your robot suppliers' support?

In a study of planning for the adoption of AMTs, Sohal et al found that one of the most important sources of information for AMT investment was information gained from suppliers [8]. Figure 6 shows the perception of the quality of the technical and maintenance support provided to the respondents from the chosen robot suppliers. The majority (68%) of the Australian companies found the level of supplier support to be "good" and 11% claimed that it was poor. The Spanish industry survey found that over 50% of the firms had frequent meetings with their suppliers during the feasibility study stage and that 84% of the suppliers were chosen on the basis of their technical capacity. This suggests that the majority of the Spanish companies which had installed robots also found supplier support to be satisfactory.

Figure 6: The quality of the Australian robot supplier's support.



Do you have plans to install more robots?

In the Australian survey, at least 70% of the companies who responded had future plans to install more robots. In Sohal et al.'s study of planning for the adoption of AMT, over 90% of the respondents indicated that there had been more than one AMT investment in their company [8]. Eighty-four percent of the companies in the Spanish industry survey had plans to acquire more robots, 45% of which planned to acquire more robots for the same applications.

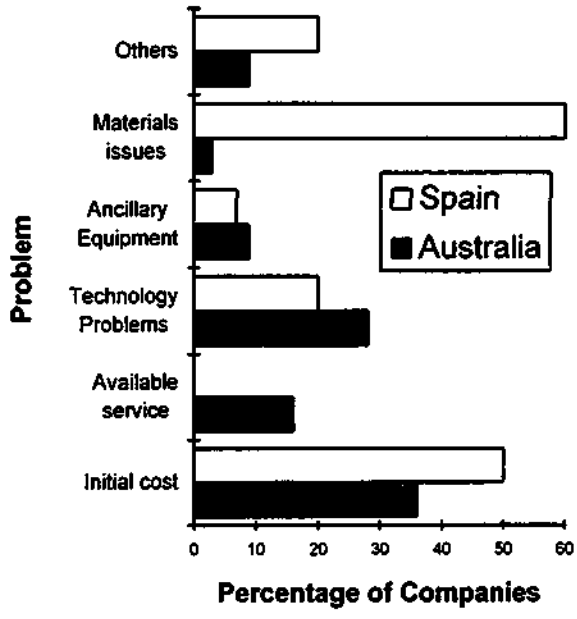
It was also found that for the Australian survey, no respondents had removed their robots from any process. This information was not collected in the Spanish survey. It could be argued that this result was due to response bias, but it is more likely that because Australia and Spain were slower to introduce robots than other countries, such as Japan, the technology had matured and there were more examples to learn from. This would have resulted in a greater degree of satisfaction and desire to install more robots. This high level of intent to install more robots may be in part due to organisations adopting lean manufacturing and an increased focus on effective human resource utilisation and process quality.

In Japan, robots and automation are used to free process workers from manual tasks and make them more available for tasks requiring decision making [13]. This forms part of a national objective to make the best use of employees. It also requires specialised skill development and training.

What are the shortcomings of robot technology?

Figure 7 shows the frequency of identification of some of the more commonly identified robot technology shortcomings. Initial costs were cited by the majority of respondents in both surveys, with the exception of material issues in the Spanish survey. These findings indicate a low sensitivity to operating costs in both surveys. This could mean either that operating costs are not considered to be significant, or that the respondents were less aware of these costs. Other problems cited by the Spanish respondents were inadequacies in robot technology and associated equipment. The material issues were probably due to the difficulty in obtaining raw materials to use with the robots that were sufficiently consistent for automated manufacturing. Most organisations which install robots find that workers cope better than robots with variations in raw material characteristics [15].

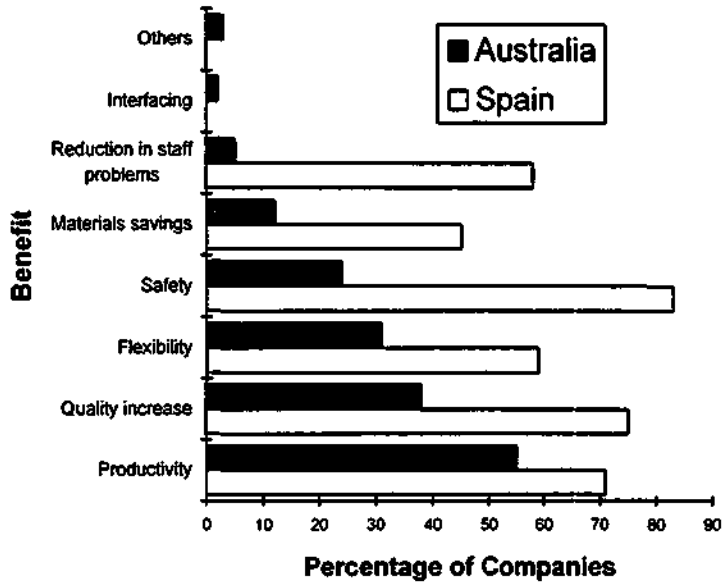
Figure 7: The shortcomings of robot technology.



What are the benefits associated with robot technology?

Figure 8 depicts the benefits that were associated with the utilisation of robot technology. In the Australian survey, the productivity increase is cited as the major benefit (55%). The next most frequently identified benefit was 'quality increase' in the Australian survey. This focus on quality reflects manufacturers' increasing need to take advantage of all opportunities to increase quality. Flexibility was also identified to be an important advantage for 32% of the Australian respondents and 59% of the Spanish respondents. In the Spanish industry survey the companies also identified increased technical experience, better working conditions and a reduction in operating (labour) costs as being benefits which they derived from robots. These categories were not identified by the Australian respondents who appeared to be more focused on production outputs, such as quality and productivity. According to Sohal et al.'s [8] study of planning for the adoption of AMTs, improvements in quality, obtaining a competitive advantage, reducing costs, increasing production and increasing flexibility were the most commonly identified benefits of AMTs. This agrees quite well with both the Australian and Spanish survey findings.

Figure 8: The benefits associated with robot technology.

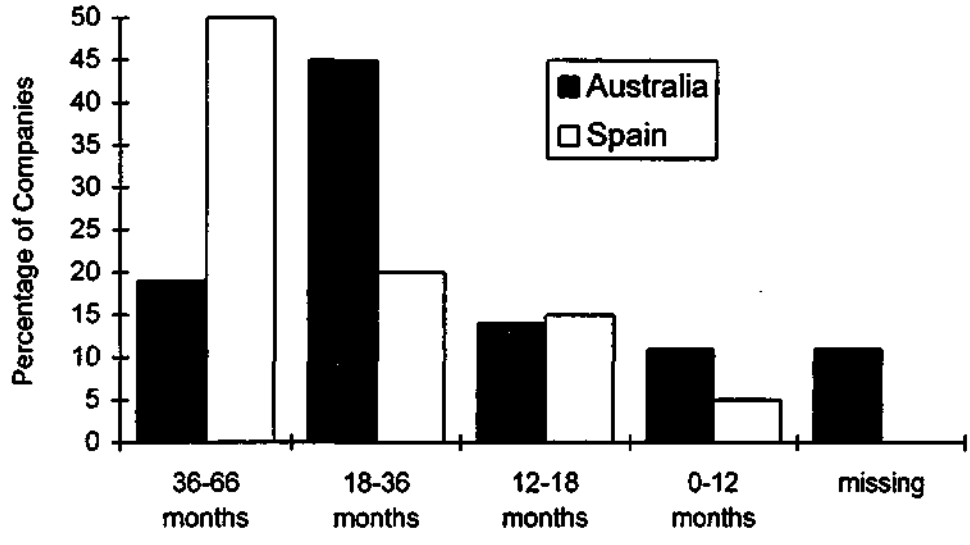


What payback period did you achieve with your robot installations?

In Sohal et al.'s study of planning for the adoption of AMTs, over 80% of the respondents used the payback method to evaluate their AMT investments, making it the most popular method [8]. The payback periods experienced by the respondents are depicted in Figure 9. The Spanish industry survey found that the anticipated average payback period was 4.2 years, while the actual payback achieved was actually 3.9 years. Manufacturers in the US also tended to experience shorter payback periods than anticipated [2]. This is probably due to a conservative analysis of financial return from the technology investment. In many cases, the Spanish and US manufacturers would have become aware of other financial benefits arising from the technology investment after installing the robots which would have shortened the final calculated payback period. Discussions with Australian manufacturers who had installed robots indicated that they correctly predicted or underestimated the payback periods for their robot installations. This may reflect a higher expectation of this technology, resulting from observations of neighbouring countries such as Japan and the success they have achieved with this technology.

The Spanish payback periods are slightly longer than the Australian payback periods, but are in reasonable agreement. The most common payback period in the Australian survey was 18-36 months. This reflects a demand from both industries for shorter rates of return on investment from technology. Industry may also perceive that projects with a payback period of less than 36 months may have a greater likelihood of success and thus be more likely to approve projects in this category. This does not compare with the practices of Japanese organisations where approved project payback periods can be much longer.

Figure 9: Payback period achieved with the robot installations.



CONCLUSION

Generally, the respondents to both surveys found that the expectations of management were realised by their robot systems. The managers participating in these surveys believed that the reactions of the process workers to automation were also generally positive. This suggests that robots are moving into the mature phase of their technology life-cycle for the industries represented by the participants and the robot types they utilised. These industries were the major users of robots [5]. This observation is further supported by the fact that the integration of robot technology into the manufacturing process was usually found to be either acceptable or completely satisfactory. There were some barriers to the adoption of robot technology identified such as the capital outlay required and there was also a slight reduction in satisfaction levels in the Australian survey relative to the Spanish survey.

Most manufacturing companies in both countries found that the support available to them from their suppliers was adequate or more than adequate for their needs. This would suggest that the main avenues for improvement in the application of robot technology lie in effective technology management. The management of AMTs has been the subject of many recent surveys [8, 9, 10, 11, 14, 15], as briefly discussed in the literature reviewed earlier in this paper. Manufacturers can draw much from this sort of research when developing effective technology management strategies. These papers suggest that the essential components of a strategy for effective robot technology usage would include line flow balancing, unmanned production shifts, flexible manufacturing systems, group technology and focussed training.

The financial return from robot technology adoption appears to be quite satisfactory in both countries as well, as most companies were able to achieve or expected to achieve a payback period of three years, or better. In this regard robots compare quite competitively with other AMTs, which have been shown to take up to 4 years to implement in the Australian context [10]. Studies have also shown that investment in AMTs has a number of less identifiable benefits which are usually

not factored into payback analyses [12, 17, 18] and which would reduce the true payback period for well planned robot installations. Some of these benefits include:

- Increased technology awareness.
- More effective leadership.
- Improved product quality.
- Lower stock levels and work in progress.
- Improvements in shopfloor morale.
- Increases in the speed of production of customised products for niche markets.

The automotive and general manufacturing industries were the dominant users of robots in both the Australian and Spanish survey. This popularity could have been driven by the need to automate the more tedious and unrewarding processes used in these industries. This survey shows that both Australian and Spanish manufacturers consider robots to have a high value, but the number of robots in use in these countries is still small compared to Europe, America and Japan (1,900 and 1,302 versus 74,500, 40,000 and 274,000 respectively). There is still an opportunity for the further adoption of AMTs in the Australian and Spanish manufacturing industries, given that 70% of the Australian companies and 84% of the Spanish companies surveyed intended to install more robots in the future.

Competing in today's global market requires the adoption of world class manufacturing practices and processes. AMTs are part of this and consequently must be part of the manufacturing strategy for all organisations which seek to be world competitive. The failure to adopt such technologies in a rational and effective manner may not just lead to the loss of production improvement gains, but it may actually result in the loss of market share.

APPENDIX A QUESTIONNAIRE

Monash University Survey of Robot Based Manufacturing

If any of the following questions are not applicable to your Company please note N/A against the question.

1. How many robots? (tick appropriate box)

1 - 5	☐	6 - 10	☐
11 - 20	☐	> 20	☐

2. Please tick the industry which best describes your company's major activities.

Clothing, Textiles and Footwear	☐
Wood and Wood Products including Furniture	☐
Petroleum, Chemicals and Products From Coal	☐
Mineral Products (Non Metallic)	☐
Machinery and Equipment	☐
Computer and Information Processing Equipment	☐
Electronic Components and Products	☐
Food, Beverage and Tobacco	☐
Timber, Pulp, Paper, Printing and Publishing	☐
Transport Equipment	☐
Fabricated Metal Products	☐

Other (Please specify)_____

2.1 Robot usage by industry. (Tick appropriate box)

Automotive	☐	Plastics	☐
Defence/Government	☐	Telecommunications	☐
Pharmaceutical	☐	Refining	☐

General Manufacturing (Please specify)_____

_____

2.2 What manufacturing processes have been automated?

_____

_____

2.3 In which processes has automation been removed?

_____

_____

3 What were management attitudes before/after installing robots? (Tick appropriate boxes)

Before: Had to be Convinced	☐	For Robots	☐		
After: Against	☐	Indifferent	☐	For Robots	☐

4 **How did your initial expectations rate against your experiences after installing robots? (Tick appropriate box)**

Low ☐ Correct ☐ Too High ☐

5 **How satisfied were you once your robot system was installed? (Tick appropriate box)**

Not Acceptable ☐ Acceptable ☐ Completely Satisfied ☐

6 **Do you have a policy of no retrenchments through automation? (Tick appropriate box)**

Yes ☐ No ☐

7 **Shop floor workers' responses to automation (Tick appropriate box)**

Negative ☐ None ☐ Positive ☐

8 **Do you hold advance discussions with shop floor workers' prior to automation? (Tick appropriate box)**

Yes ☐ No ☐

9 **How good is your robot equipment supplier support? (Tick appropriate box)**

Poor ☐ Indifferent ☐ Good ☐

10 **What is your opinion as to the general value of robots for Australia? (Tick appropriate box)**

Low ☐ Medium ☐ High ☐

11 **Do you have plans to install more robots? (Tick appropriate box)**

Yes ☐ No ☐

12 **Short comings in robot technology (Tick appropriate boxes)**

Programming	☐	Initial Cost	☐
Ongoing Cost	☐	Cell Design	☐
Available Service	☐	Robot Vision	☐
Raw Materials	☐		

Others (Please specify)_____

13 **Benefits associated with robots (Tick appropriate boxes)**

Flexibility	☐	Materials Savings	☐
Interfacing	☐	Productivity	☐
Safety	☐	Staff Problems	☐
Quality Increase	☐		

Others (Please specify)_____

14 **Pay-back period (Tick appropriate box)**

0 - 12 months	☐	12 - 18 months	☐
18 - 36 months	☐	36 - 66 months	☐

15 **Difficulty of financial justification (Tick appropriate box)**

Low ☐ Medium ☐ High ☐

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