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LOCAL DECISION RULES: COMPLEXITY OR CHAOS?

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INTRODUCTION

This paper examines the impact of "local rules" on the stability and performance of a manufacturing system. The ability of systems to maintain themselves in, and move between, stable, complex and chaotic states has been widely documented.(Gleick, 1986, Waldrop, 1992). The Beer Game is an example of a social-technical system that quickly moves to and maintains itself in a chaotic state as a result of the "local rules" used by the actors. (Thomsen, Mosekilde and Sterman 1992, Paich and Sterman, 1993). Other research indicates that such "local rules" can produce "edge of chaos" states where systems are responsive and adaptive (Langton, Taylor, Farmer, Rassmussen 1992).

THE RESEARCH PROBLEM

The first stage of the research was to identify a system that had might have equilibrium states that would be disturbed by local rules or which may have unstable equilibria points that may be stabilized by local rules.. The Kan Ban system was chosen because it represents an example of a human decision system (the rules of the Kan Ban System) that is designed to produce stable behaviour at the interface of a manufacturing and an assembly system. Anecdotal material indicated that frequent managerial intervention was required to modify and stabilize the performance of the system. It was decided to investigate the impact of these interventions to test the hypothesis that local rules, in this case managerial interventions, produce stable systems. To do this, the first requirement was to be understand whether the Kan Ban system was a stable or chaotic system in its original or "pure" configuration. To do this it was necessary to model the system using the settings that management used to get optimum performance from the system. The strength of simulation methodology is that it allows the testing of the original assumptions of management about the functioning of the system to be tested in a manner that excludes the day to day variations of the factory floor. Once the stability (or otherwise) of the system was ascertained, it was necessary to understand the impact of various local rules. This would be done by modelling each local rule and examining its impact.

THE KAN BAN SYSTEM

The system that is being modelled is a Kan Ban system in a high-tech manufacturing plant in Melbourne, Australia. The Kan Ban system, which is part of a Just-in-Time system, is designed to maximize the cost efficiency of the inventory holding system by maintaining minimum inventory. The system used in this study has been described by Coghill[1] and consists of two systems with shared interdependence; an assembly area and a machine shop. The company makes Optical Spectrometers which are assembled using a combination of on-site manufacturing and purchased parts. The Kan Ban system is designed to achieve the minimum inventory holdings of manufactured parts. The Kan Ban system seeks to optimize the number of parts made in each production run and the time at which the parts are ordered. In doing this, a balance is sought between the cost of holding parts and the economies of scale in making large quantities. In principle, the holdings of any part are calculated so that a new shipment arrives just as the last one from the previous batch is used

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[1] Coghill, J.M. *"Implementation of JIT/Kan Ban in a low volume, high variability environment."* Pacific Conveyance on Manufacturing, Australia, 1990 pp 1067 - 1076

1 The rate at which the parts will be used during the year given projections of demand.

2 The Economic Order Quantity (EOQ).

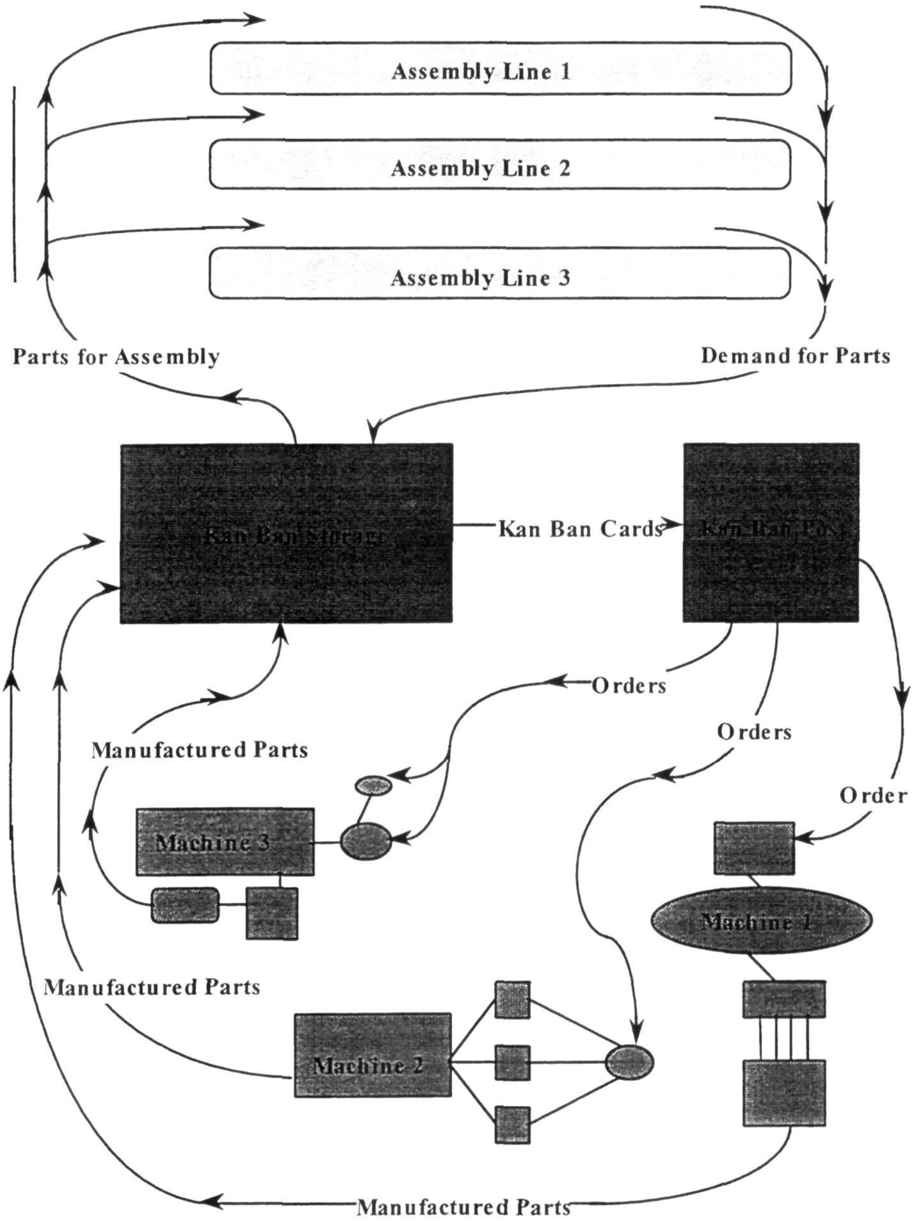
3 The time to produce the EOQ

4 The re-order point, which allows sufficient time for the part to be made before the Kan Ban bin becomes empty.

There are a number of assumptions that are built into these calculations. Firstly, that demand will remain as predicted. Secondly, that there will be no strikes, machine breakdowns or illness amongst key operators.

The simulation is able to replicate these assumptions and provide information on the functioning of the system as its designers envisaged it. It is not possible to observe the system running under these assumptions on the factory floor because fluctuations in demand, breakdowns, etc occur. However, they also mask the true functioning of the system and make it impossible for the managers to see whether the Kan Ban system is working.

The layout of the factory is as follows:



RESEARCH METHODOLOGY

The case study is based on research done at a high-tech manufacturing firm in Melbourne, Australia where a Kan Ban system was used. A simulation model was built of this Kan Ban manufacturing system which had a set of formal rules for the operation of the system, based on Economic Order Quantities (EOQ), re-order points and order quantities, for the parts that are manufactured for the assembly line. These rules are calculated by management and "hard wired" into the system on Kan Ban cards. These rules are designed to minimize stock holdings and eliminate stock-outs. This gives rise to the "Just-in-Time" concept of inventory control. The parts are manufactured and delivered just in time to be used in the assembly process. Interviews were held with management and worker to formulate the rules that were used.

1. The Model

The software package "iThink" was used because it would model the continuous manufacturing process and the discrete process of local decision rules. An additional advantage was that the company's management had experience with the package which made explanation of the research and the results easier. The software version was iThink RISC 3.0.6b6.2 running on a Power Mac 9500 using 65 MG of RAM.

Figure 1 shows the iThink model developed to simulate the local rules of the Kan Ban system

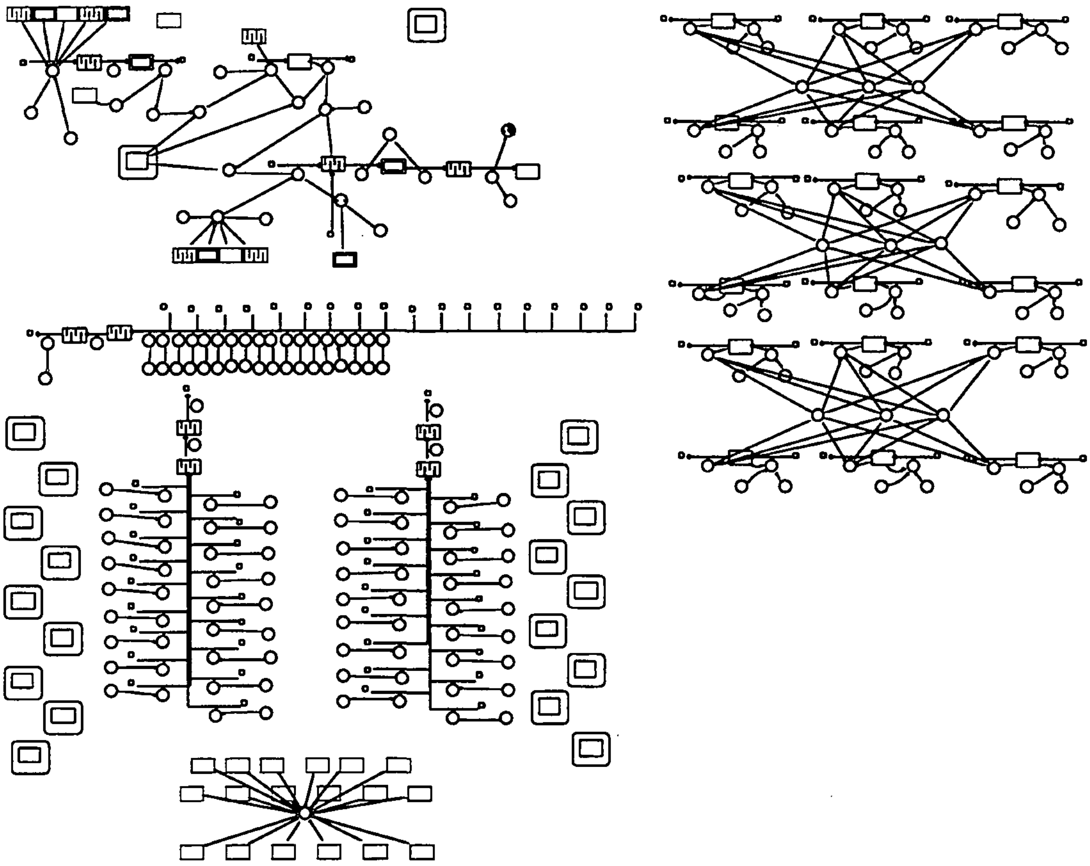


Figure 1 Complete Kan Ban Simulation

Figure 2 shows how the usage of the parts was modelled in this section of the simulation. In the main model this section is at the sub-model level and not visible. There were 18 of these sub-models to model the 18 parts that were produced by the Toshiba.

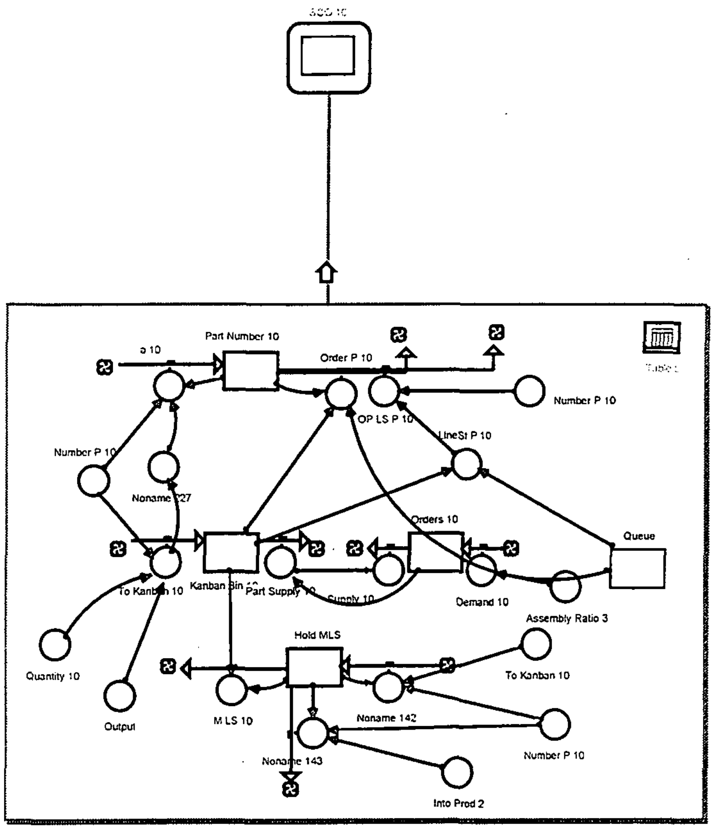


Figure 2 Detail from Kan Ban simulation: Parts Usage

Figure 3 shows the first of two of the queue systems for the Kan Ban model. This queue modelled the system in its initial state, that is before any imposition of local rules. The ghosted regulators are taken from the sub-models shown in Figure 2.

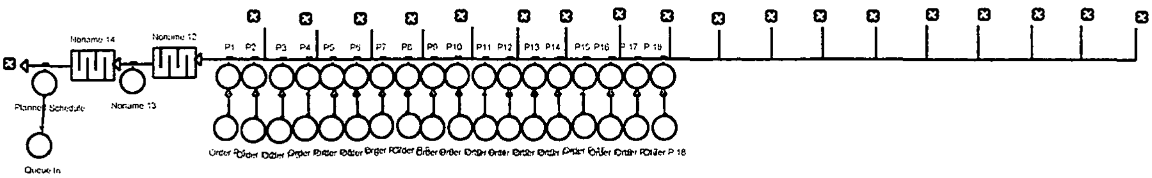


Figure 3: Detail from Kan Ban simulation: Initial state queue.

Figure 4 shows the second of two queues used in the simulation. In this case it is the queue for the operator line stops, where the operator moves their card to the front of the queue if the queue has more than five cards in it. It was necessary to model these two queues separately as they entered the machine queue at different points.

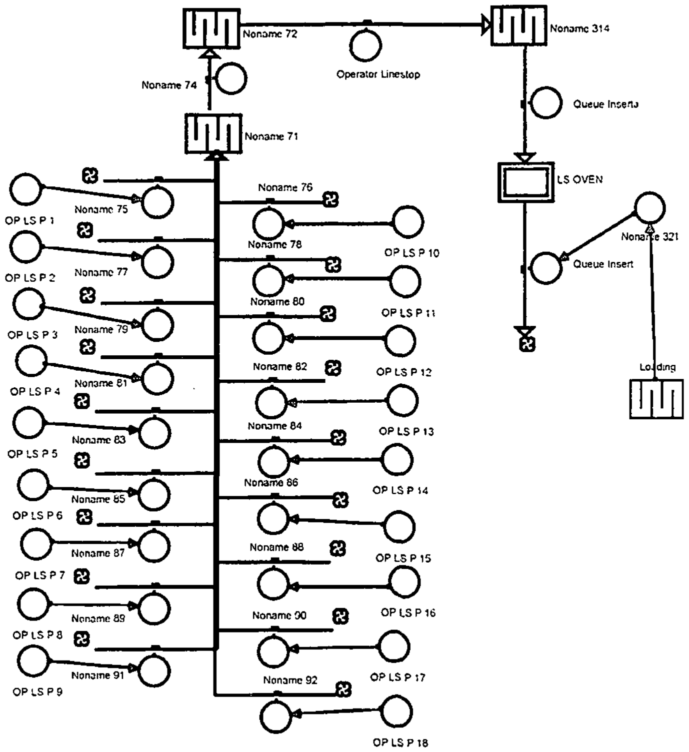


Figure 4: Detail from Kan Ban simulation: Operator line stop queue..

Figure 5 shows the central core of the model is the queueing system for the machine (labelled "Toshiba) which makes the parts. The operation of this queue is modelled with two concerns. First, it was necessary to keep the cards "visible" as the worked their way through the queue. This was to enable the simulation to remove them from their queued position if they were moved to the front of the queue under the manager's linestop rule. This was achieved using the sub model "Nets" where cards that were moved were captured as they became visible to the software in the regulators, Withdrawal 1, 2 and 3. The second concern was that, given the complexity of the queue it was necessary to ensure that cards arriving at the beginning of the queue were placed as high up as possible in the queue. This was done using a logic statement in the form,

if (No_Queue_Entry=Planned_Schedule) then (0) else (if (Loading>0 or Waiting_Loading>0 or Q1>0 or Q1a>0 or Toshiba_1>0) then (Planned_schedule) else (0)).

The effect of this statement is to allow entry at the beginning of the queue only if all other points of the queue are empty. There were corresponding statements controlling entry to all other points in the queue.

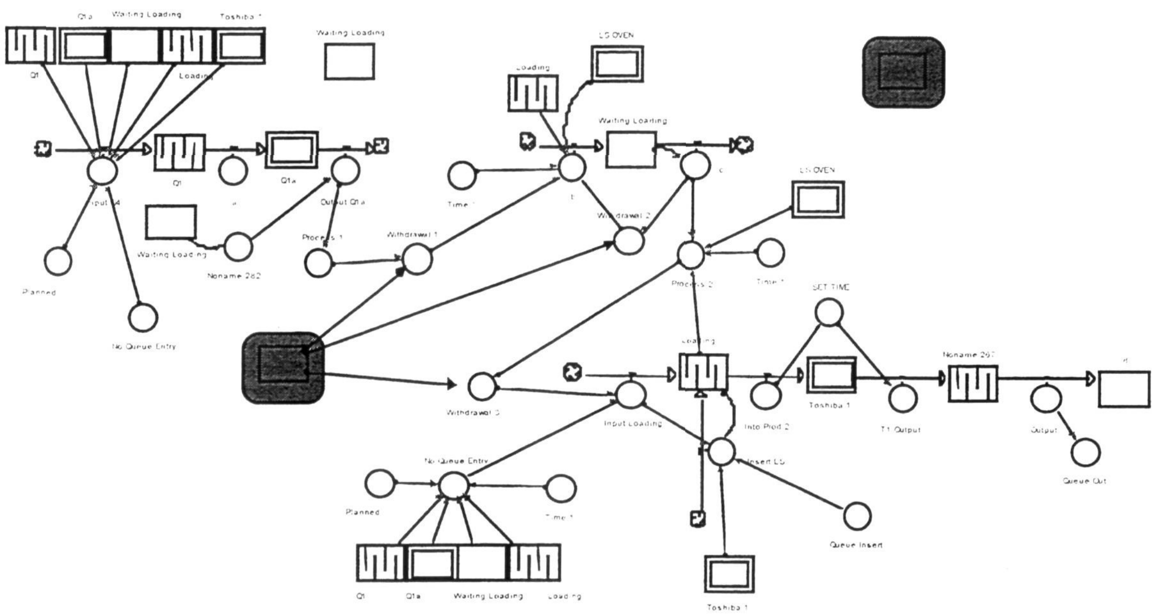


Figure 5: Detail from Kan Ban simulation: Main queue to machine.

2. Interviews

Interviews in the firm indicated that, in addition to these formal rules, there are informal "local rules" used by management and operators in their efforts to compensate for variability induced by the formal rules. These rules were:

Management	If a Kan Ban bin becomes empty while the Kan Ban card is in the queue, then the card is put to the front of the queue.
Operators	If queue length is above about five, put your Kan Ban card at the front of the queue.
	If you look like being busy, move cards of parts you are going to need into the queue before their re-order point is reached.
	If you look like being busy and you are going to run out of parts and the machine operator is a friend, by-pass the Kan Ban queue altogether and ask the operator to make your part next.

Eliciting this information proved to be difficult. The manager was quite prepared to discuss the rules that he used. There were two reasons for this. First he had designed the original set of EOQ rules and had high "ownership" of the system. Second, he saw it as his responsibility to keep the system working and this legitimatized his use of local rules. For the workers however, the situation was different. They were using local rules in ways that management did not sanction and were reticent to discuss the use of local rules. This was compounded by the fact that one interviewer had significant visibility as a consultant to management. Assurances of confidentiality and a change of interviewer began to improve the situation when a State government election brought a party to power which had promised a significant reduction in Unfair Dismissal laws. At this point the flow of volunteer interviewees dried up. Fortunately, the information from the interviews was beginning to be repetitive and it was assumed that enough information had been gathered.

3. Simulation Results

The following rules were simulated.

Rule 1 Formal "hardwired" rules only

Rule 2 Management's rule: "If a Kan Ban bin becomes empty while the Kan ban card is in the queue, then the card is put to the front of the queue."

Rule 3 Operators' rule: If queue length is above about five, don't put the Kan ban card at the back of the queue, put it at the front.

Rule 4 Rule 2 + Rule 3

The results for the quantities of part in the Kan Ban bins for parts 5 and 12 are in Appendix 1.

OBSERVATIONS:

1 The application of Rule 2 (the manager's rule) produces greater stability than is present with Rule 1 (formal rules only)

2 The application of Rule 3 (the operators' rule) produces less stability than the manager's rule and during the periods of application appears to increase instability over the formal rules.

3 The application of both Rules 2 and 3 appears to create a level of stability than rule 3, but performs less well than rule 2.

4 Total application of Rules 2 and 3 together are fewer than Rules 2 and 3 applied separately.

5 Total system performance, measured in total stock-out hours (tsohrs), is best under the application of Rules 2 and 3.

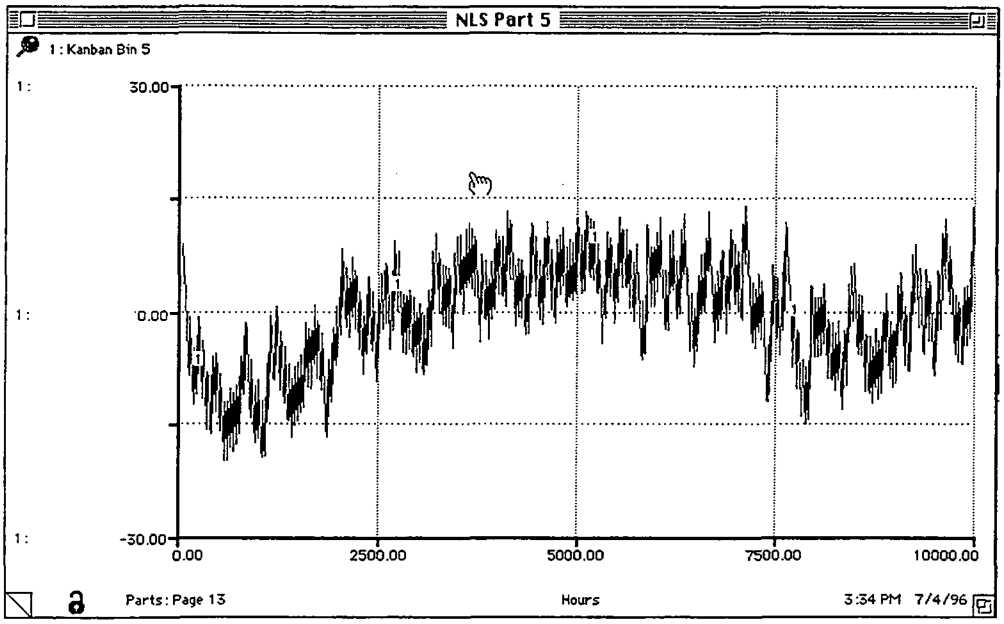
Total Stockout Hours

Rule 1	Rule 2	Rule 3	Rule 2 + 3
5040	1743	5314	1788

Further Analysis.

The results so far indicate that there are changes in the system as a result of the local rules used by the managers and the operators. In order to be able to measure the extent to which each local rule stabilized or destabilized the system, the data was analyzed using the Fast Fourier Transformation (FFT) in SPSS. Linear regression was used to analyze the logs of the FFT. The results are Shown in Appendix One. It was hoped that the Gradients of the regression would provide a measure of the stability of each set of data, with a gradient of -1 indicating a stable system and a gradient of 0 indicating a chaotic system. In other words, provide a measure of the extent to which each local rule stabilizes or destabilizes the system. The gradients for the regression of Part 5 are shown in summary. As can be seen the results are exactly the opposite of what would be expected, with what appears to be the most unstable of examples, namely Rules 1 and 3 having the highest values and the two most stable patterns having the lowest values. Nonetheless, this method while contradictory may provide discrimination between the impacts of the local rules.

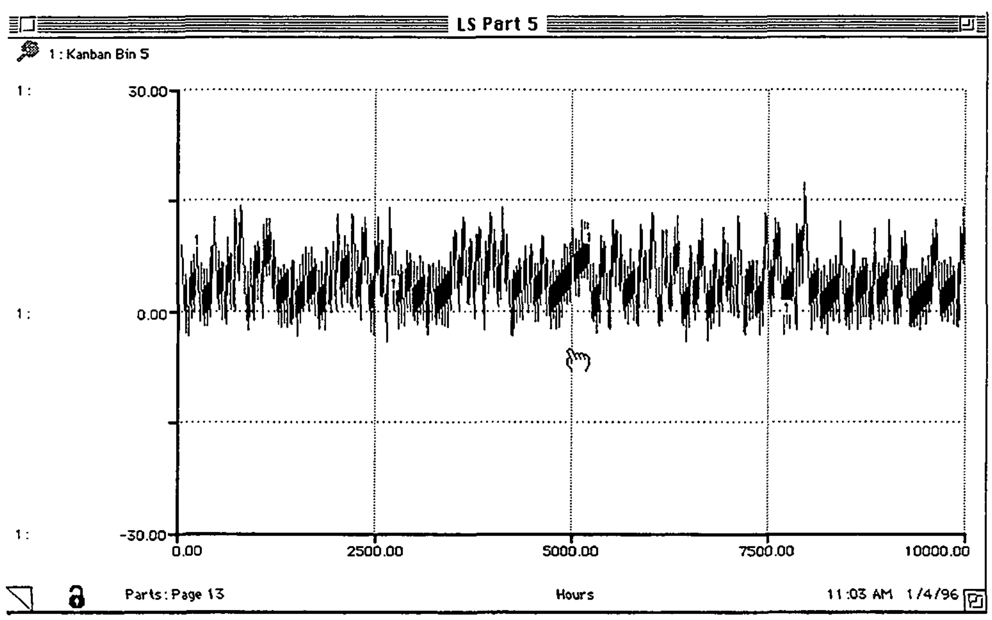
Examples of Part Performance and Gradients of Log/FFT



Part No 5 performance under Rule 1

Variable B

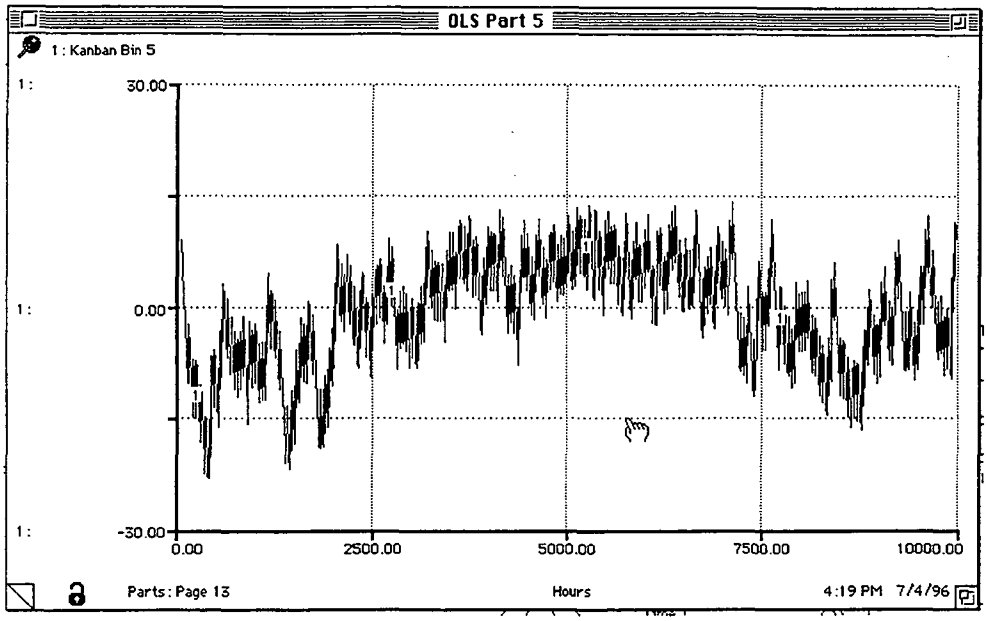
LOG -.786749



Part No 5 performance under Rule 2

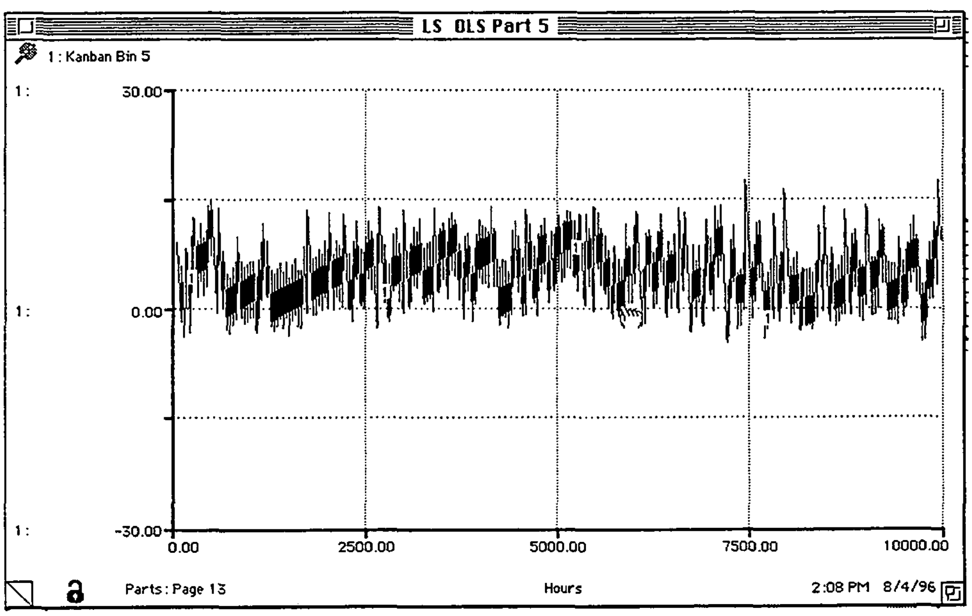
Variable B

LOG -.778279



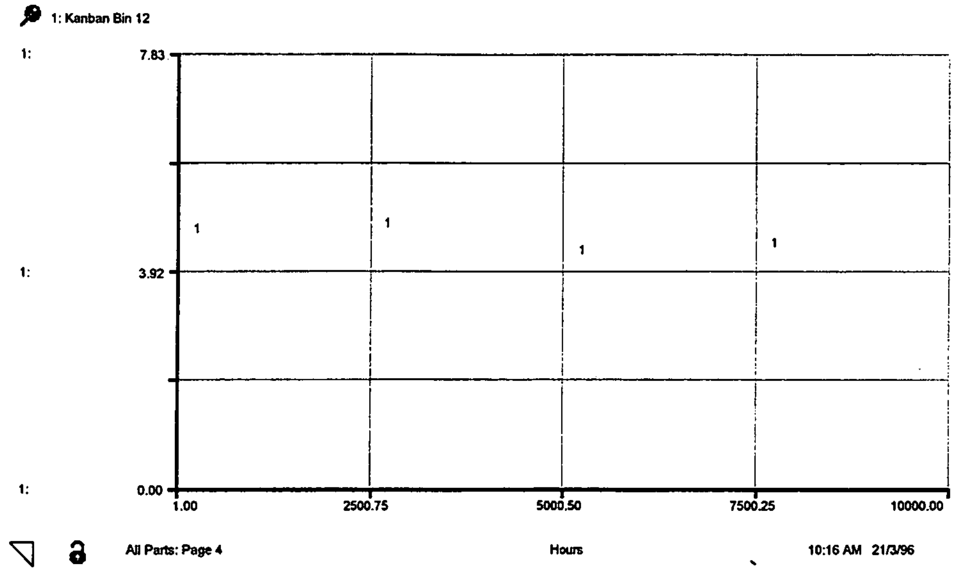
Part No 5 performance under Rule 3

Variable	B
LOG	-.798567



Part No 5 performance under Rules 2 + 3

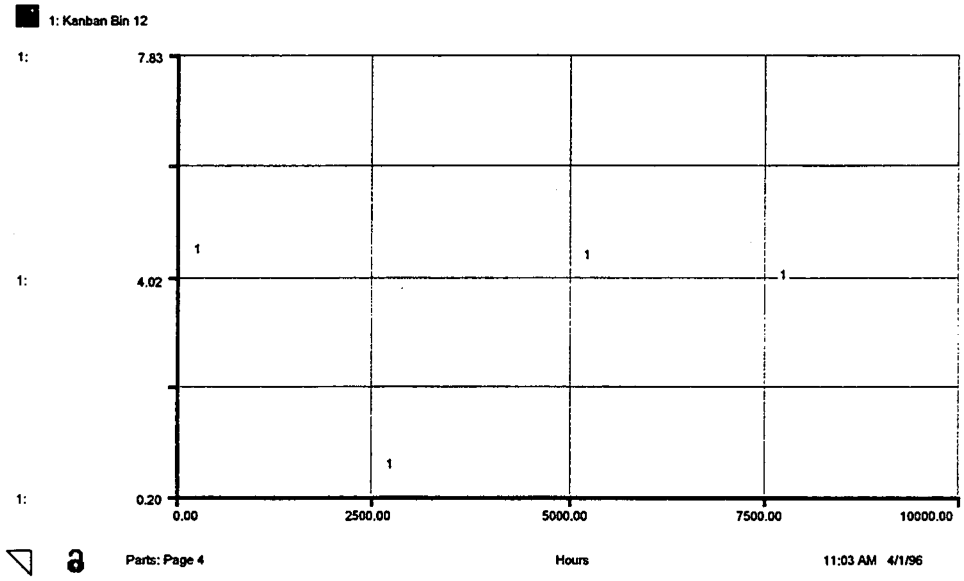
Variable	B
LOG	-.776456



Part No 12 performance under Rule 1

Variable B

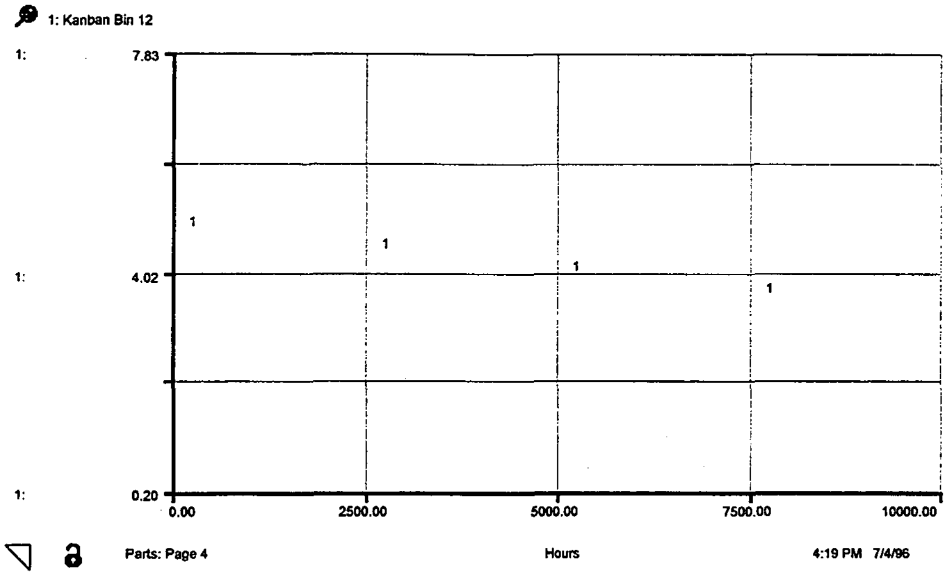
LOG -.804859



Part No 12 performance under Rule 2

Variable B

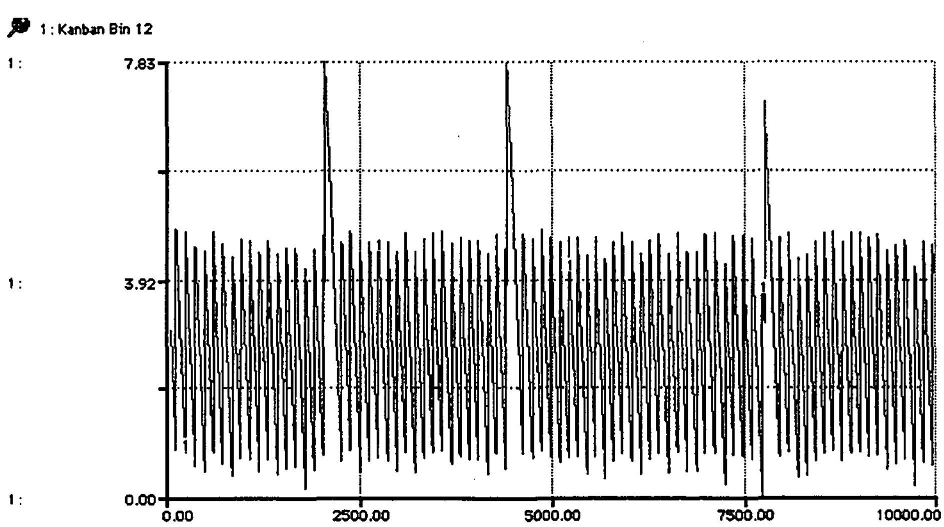
LOG -.737188



Part No 12 performance under Rule 3

Variable B

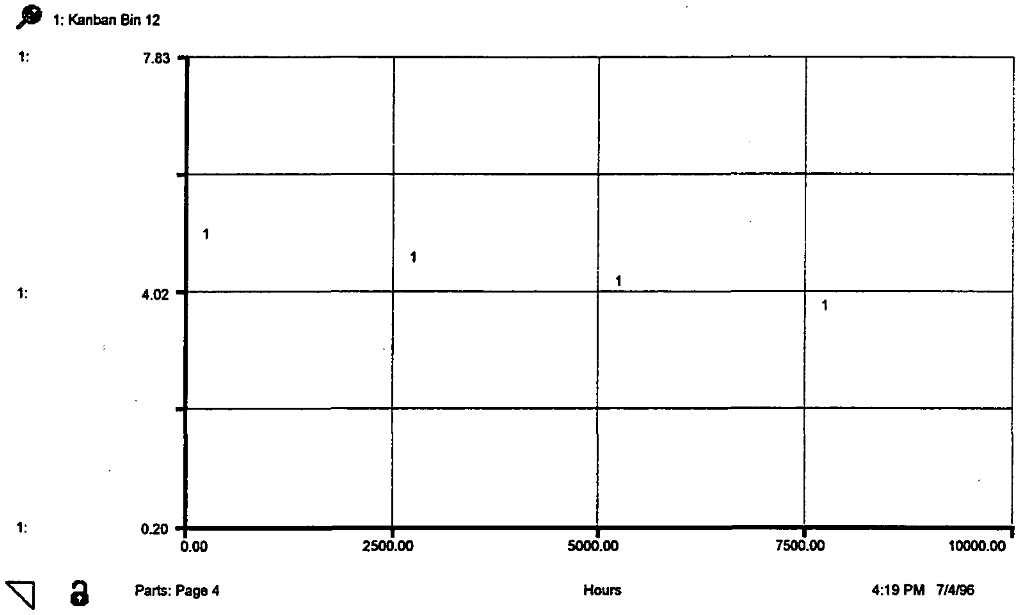
LOG -.796434



Part No 12 performance under Rules 2 + 3

Variable B

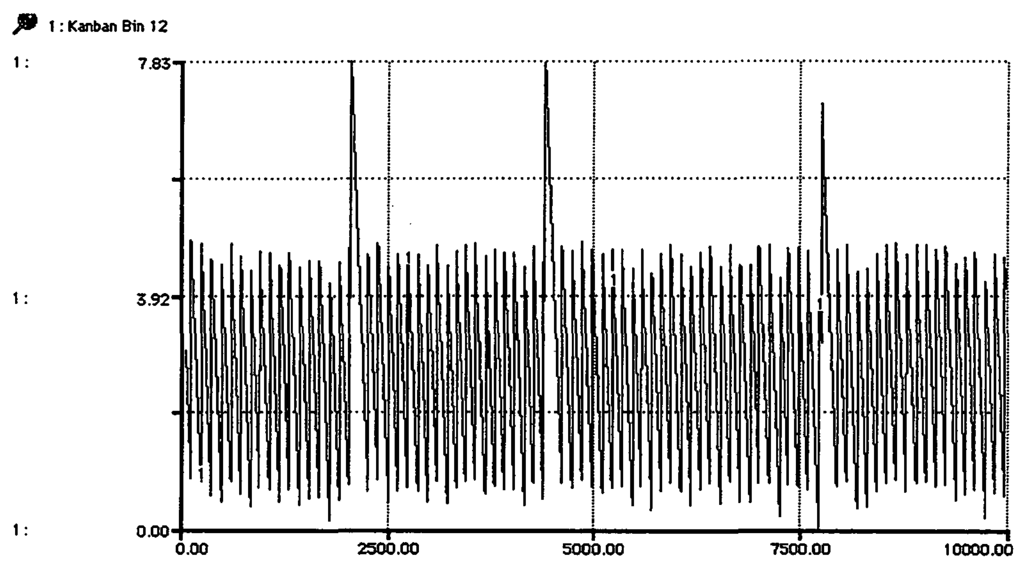
LOG -.827502



Part No 12 performance under Rule 3

Variable B

LOG -.796434



Part No 12 performance under Rules 2 + 3

Variable B

LOG -.827502

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