Efficient Parts Supply: Influence of Information Flows

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Abstract

We investigate parts supply from one supplier to a manufacturer who operates a very variable final assembly schedule with kanbans for parts supply to the production line and from suppliers.

The information flow includes kanbans for resupplying the line from the factory store and restocking the factory store from the supplier, one week ahead forecasts of parts requirements, 8-week ahead requirements and updated orders supplied weekly, and a six month MRP schedule supplied fortnightly. The supplier uses these to schedule raw materials preparation, initial assembly on a bottleneck machine, and finishing. This is challenging given the conflicts between the pieces of information.

We investigate ways to improve total system performance, particularly inventory levels and easier production scheduling of critical machines, given the delays and structure of the system, using system dynamics models built in ithink!

Kanban numbers can be reduced without risking production interruptions. The one week ahead forecasts offer little useful information to the supplier. Shifting to a simpler scheduling mechanism for the initial assembly is helpful.

We have investigated two processes in the manufacturing logistics system, parts flow internal to the manufacturer and to the supplier, and the linkage between parts usage by the manufacturer and parts production by the supplier. They can be simplified and improved, reducing inventory holdings and hence cost, without compromising the overall responsiveness of the manufacturer which is a distinctive competitive characteristic. Simplified information flow processes allow for easier, better operation of the total system.

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INTRODUCTION

There are a variety of ways to organise and schedule the flow of work through a manufacturing system, both in the longer term (one to six months ahead) and in the short term, (one day - one month ahead). Some systems are push systems. Plans for future production are formulated, material needs are established in terms of timing and volume, and work is pushed out on to the factory floor. A typical example is a production system in which an aggregate plan, then a master production schedule and a final assembly schedule are prepared. The MPS is used to generate the materials requirement plan (MRP) which determines which materials are pushed into the factory when. It also indicates what raw materials are required from the supplier and when.

In a pull system, however, materials are pulled through the manufacturing process, often using a single or dual kanban card system. Final orders signal the pull of materials through the final manufacturing stage. As the output from each stage is pulled forward, the signal is given to that stage to produce more, but only up to a specified quantity. In a completely JIT environment, this pull cascades through the process to the input of raw materials, and through to the acquisition of materials from the suppliers. Typically, there is some planning mechanism which indicates proposed production schedules and materials requirements, but this does not control the actual production process as it does for the push system.

Many production systems use a combination of both approaches. A possibility is kanban control for part of the manufacturing process and push control for the remainder, and for the ordering process to suppliers. Another alternative is to use a kanban system to pull materials from suppliers up to some agreed aggregate quantity. Particular features of the systems tend to be determined by each manufacturer. Additional complexity arises when considering a manufacturer and a supplier as a linked system.

There is considerable interest in how best to establish and manage pull-type production systems. Singh and Brar [1992] review activities in design, planning, and control of pure JIT systems. They identify studies using analytical approaches, simulation, system dynamics, and empirical studies, which indicates the variety of approaches available to assist in these tasks. They assert that system dynamics is a fruitful means to use because the methodology is ideally suited to investigating systems in which there is feedback control, interactions between stages and sub systems, and dynamic behaviour is a function of the systems structure. Mejabi and Wasserman [1992(a), 1992(b)] contend that a critical element required in any simulation system to successfully model JIT systems is a construct for modelling the pull characteristics, where the information flow is in the opposite direction to the materials flow. They recognise also the need to interface models of JIT systems with those of push-based production systems, as many production systems incorporate elements of both. They propose the addition of some constructs or model elements specifically to the SIMAN discrete event stochastic simulation system, and they do recognise that similar constructs could be added to other simulation languages. Gupta and Gupta (1989) describe a detailed study of a multi level, multistage JIT system using Dynamo. They investigate the impact on work-in-progress, capacity utilisation and stock out duration of such aspects as stoppages, number and size of kanban containers, variability in supply rates, processing time, and demand. It is a test scenario, not a model of an existing system.

The system we investigate comprises a manufacturer and a supplier. The manufacturer recently switched to kanban control of its production lines and of the acquisition of parts from suppliers. However, the supplier is still using a conventional system, with the initial processing of parts being based on MRP schedules from the manufacturer. The critical stages of the manufacturer's system are the incoming parts store, the parts available on the factory floor, and the hourly demand for these parts. The supplier operates a three stage production system to prepare materials, make sub-assemblies, and finish the part for supply to the manufacturer. Inventory was building up at the supplier and there was uncertainty about the number of kanbans to use to guard against stockout on the factory floor whilst also maintaining low stocks.

Although this is a specific case, the principles being investigated are expected to be of wider interest. In particular, we investigate the linkage of two production systems across the manufacturer-supplier interface and the impact of varied information flows across it. We use system dynamics modelling which easily incorporates the feedback control required for a pull system, as well as modelling satisfactorily the different types of production systems. We incorporate stochastic features such as final demand variation, and quantity and scheduling variation at the supplier. We produce a model which allows the interested parties to readily observe the impact of various proposals, such as reduction in kanbans, increase in demand variability, and changes in scheduling rules.

We describe the physical process flow and the information flows. We develop a system dynamics model using ithink! We identify several issues to investigate, and report on the outcome of these investigations. We conclude with remarks about the suitability of this approach and the lessons available for the managers of this particular system.

THE SITUATION

A whiteware manufacturer produces 70 to 100 models each day through one production line, with total daily output of about 800 units. The final assembly schedule, which has batch sizes of one, is highly variable, both in terms of quantity of each model and the sequence of manufacture. The supply of most parts to the factory floor from the manufacturer's store is managed by a kanban system. For most parts, acquisition from the suppliers is also managed by kanban systems. The company has only recently adopted kanban systems for their suppliers, and has been using kanban systems internally for longer. However, there is still opportunity to improve the understanding of the system within the organisation.

To model the system successfully, it is essential to describe the existing process. Figure 1 shows the physical process flow. The supplier acquires the raw materials and does some initial preparatory work on the materials. The materials remain in a work in progress store until required for the intermediate production phase or subassembly. This phase occurs on a bottleneck machine for the supplier. The subassemblies are bulky but relatively low value items. As the finished part is prone to damage, the subassemblies are stored rather than the finished part. When signalled by kanban, the finishing step on the part is completed before dispatch to the manufacturer. On receipt at the manufacturer, the parts enter a store, from which the factory floor is resupplied using a kanban system.

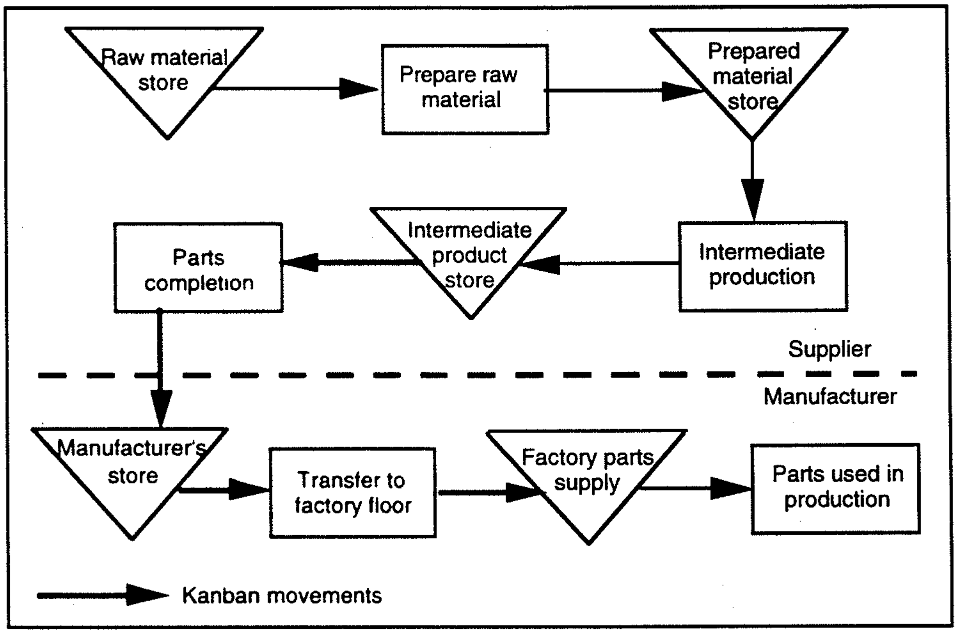

Figure 1: The physical process flow at supplier and manufacturer.

The information flow which occurs in the management of this physical process flow is in three parts. Initial estimates for parts usage are provided by the manufacturer up to six months ahead from the master production schedule and materials requirement plan. New orders are indicated for 60 days ahead. This data is used by the supplier to plan the preparation phase of the parts manufacturing. The manufacturer then develops an estimated generic production schedule for the forthcoming week. This information is used by the supplier to schedule the intermediate stage of production. Finally, parts usage on the floor and scheduling of finishing at the supplier is controlled by kanban. The detailed flows are described in Figure 2:

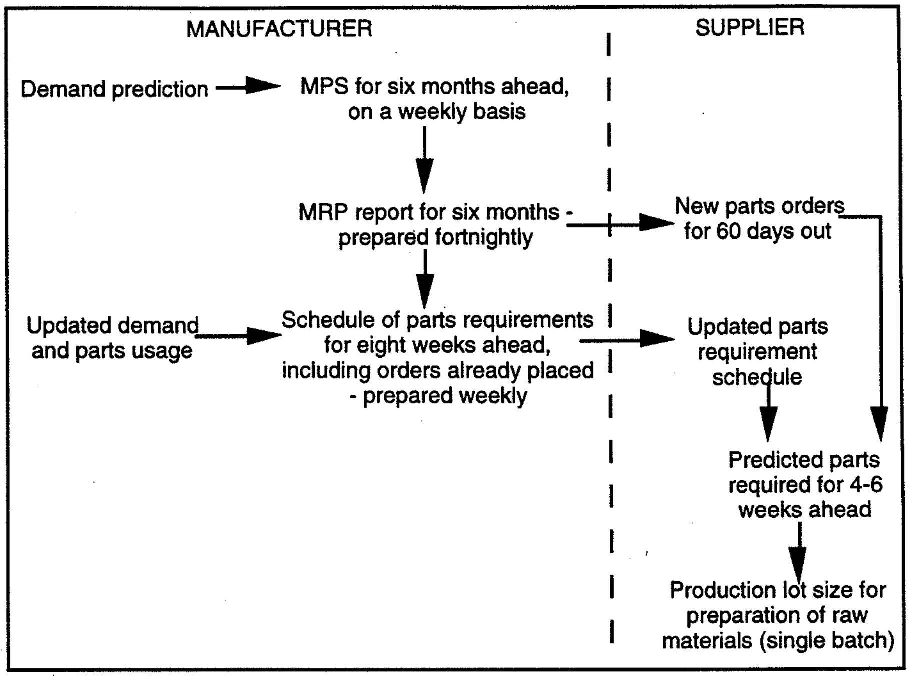

Figure 2a: Initial orders and scheduling raw materials preparation

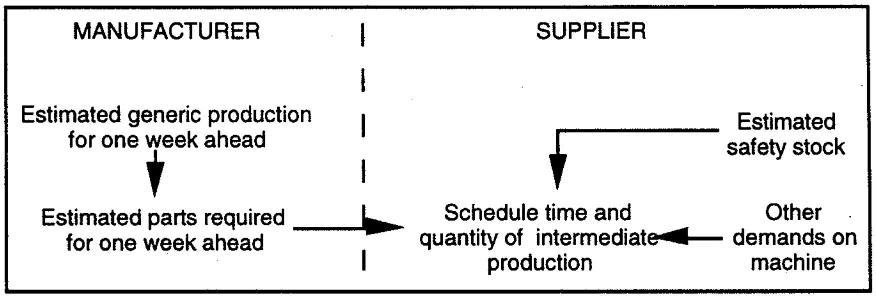

Figure 2b: Scheduling intermediate production

Essentially, three principal information flows occur. The first provides information about long term requirements and is used by the supplier to schedule the initial preparation of raw materials, and to provide some guidance about demands on the critical bottleneck intermediate production machine. The second flow gives predicted future demand in the medium term, and is used for scheduling production of the intermediate subassemblies, along with the supplier's own estimates about future demand, based on past experience. Finally, kanbans are used to replenish the factory floor, to restock the manufacturer's store, and to schedule parts completion at the supplier.

There is considerable variation in demand levels expressed by these three flows. MRP forecasted weekly usage and actual usage can vary by up to 250%. Weekly parts requirement as used by the supplier to schedule intermediate production varies by 25% to 150% from actual usage as indicated by kanbans to be filled. Consequently the supplier has considerable difficulty in determining required levels of parts production in the three stages of preparation, intermediate, and finishing. The supplier would like more certainty and more consistency in the requirements that are placed on this production system. They have requested more information and more accuracy and fewer changes to future parts requirements. However, the manufacturer regards their flexible and responsive production system as a major competitive advantage. It is of interest, therefore, to investigate how this system actually works, and to develop potential interventions to improve the situation, if needed.

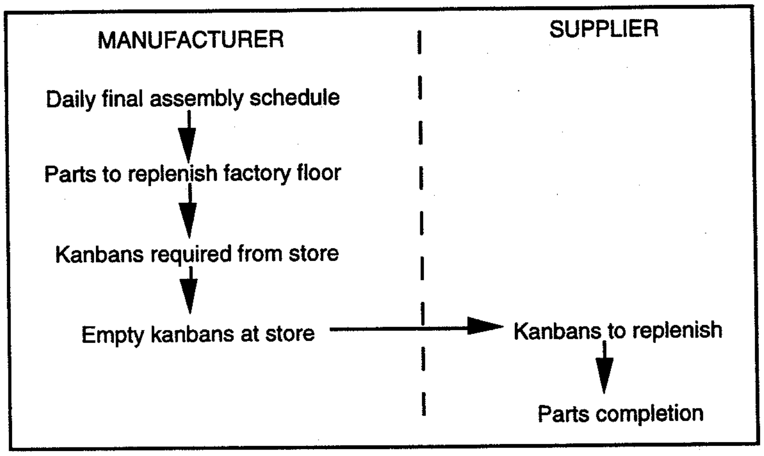

Figure 2c: Parts usage and scheduling parts completion

There are several measures of performance. For the manufacturer, these include the average stock holdings of finished parts on the factory floor and in the store, and the level of stockouts at the two locations. The supplier is concerned with the ability to finish the parts when requested so measures the average level of intermediate stock, as well as the level of stockouts. Because the intermediate parts are very bulky, the supplier is also interested in the maximum level of stocks held, as this is a principal contributor to the stock-holding cost.

THE MODEL

A system dynamics model of the linked production systems (Appendix A1) was built using ithink! It incorporates the process flow and the information flow used to control the process. The system has several delays. It takes four hours to replenish the kanban stock on the factory floor. Empty kanbans are collected from, and full kanbans delivered to, the manufacturer every four hours. Sixteen hours elapse between collection of the empty kanban from, and receipt of the refilled kanban by, the manufacturer. Raw materials are prepared once every weeks (160 hours). The quantity is fixed at a typical equivalent monthly usage as indicated by the MRP forecasts. Subassembly or intermediate production is scheduled for a random time during the 40-hour week, as this corresponds to the practise at the supplier, where the facility is used for other production as well. The quantity scheduled is modelled as uniformly distributed between the observed minimum and maximum weekly requirements as given in the estimated one week ahead usage schedule. Finishing is scheduled when empty kanbans arrive at the supplier. The hourly demand for parts is modelled as uniformly distributed between observed minimum and maximum hourly usages on the factory floor.

There are three sources of variability in the model - the hourly demand, the quantity of subassemblies produced, and the timing of this production. As is usual in a stochastic simulation model, a series of experiments is conducted, testing different seeds for each of these variations.

INVESTIGATIONS

The investigation phase consists of three parts - verification that the model is a satisfactory representation of the real system, a study to determine a satisfactory number of kanbans to ensure adequate stock supply but also to reduce stock holdings, and experiments with some simple rules for determining the timing and quantity of subassembly manufacture.

Model verification

For the verification phase, several runs of the base model were made for periods of 1280 hours (32 weeks), following a period of 720 hours for establishing an approximate steady state. Summary results indicating the variability in system performance are displayed in Table T1 (base avg, base min, base max respectively for the average of the average level over fifteen tests, min for the average minimum level, and max for the average maximum level). The observed performance was similar to that of the real system. This included occasional stockouts both on the factory floor and in the supplier's inventory of subassemblies, and high maximum stocks of subassemblies.

Kanban numbers

The existing system has twenty four kanbans circulating within it. The base case results show that the minimum number of kanbans at the manufacturer's store is about four, which suggests that the number of kanbans in the system could be safely reduced. Company personnel have been prone to arbitrarily adding or removing kanbans, without necessarily being aware of the impact of the action. This model has provided a useful tool to illustrate the effect without risking major disruption to the production systems of either the manufacturer or the supplier.

Traditional methods of setting the number of kanbans, based on transit times, stock on the floor, turnaround time from supplier, and some safety stock, suggest that between 13 and 29 kanbans are required, depending on the usage figure chosen. With predicted MRP daily usage, the figure is 13 kanbans, with average actual daily usage, the figure is 17 kanbans, and with maximum daily usage the figure is 29 kanbans, where all results are computed over six weeks.

We investigate two possibilities - a 16% reduction to 20 kanbans and a 25% reduction to 18 kanbans - and conduct a series of six tests to assess the implications of these reductions. The results are displayed in Table T1 (kanban number 24, 20, and 18, respectively).

For the reduction to 20 kanbans, the principal difference is in the level of stocks held in the manufacturer's store. Thus this reduction appears to be justified on the basis of the existing observed demand for the part.

There is some slight difference with the larger reduction to 18 kanbans. There are occasional stockouts on the factory floor and at the manufacturer's store, and a increase in the inventory of subassemblies at the supplier. This 25% reduction in kanban numbers is slightly more risky. Depending on the attitude to this risk, the reduction may or may not be justified. However, it is interesting to note that the manufacturer has in the past been willing to accommodate occasional shortages, so they may be willing to accept this risk in return for the inventory reduction that occurs.

Intermediate production scheduling

Inspection of results from the base case study show that the stockholding of subassemblies at the supplier is high at about 16% more than the average weekly requirement for subassemblies. Similarly, the maximum stockholding of subassemblies is particularly large at about 37% more than the maximum observed weekly requirements for subassemblies. Given that the parts are bulky, although low in value, this maximum is the primary determinant of the stockholding cost to the supplier. It is helpful to consider potential ways to reduce this level by better scheduling of the subassembly process. This high level of stock represents wasted production possibilities for other parts which use the facility. The lack of connection between the various information flows which control the three phases of the supplier's operation is also of concern. Given that the supplier is not disturbed by the stock levels of the prepared raw materials and seems to have no difficulties in scheduling the appropriate quantities, interest is focused on improving the schedules for the intermediate production facility.

In the existing system, the supplier schedules the production of subassemblies at some variable point during the week. The volume scheduled is estimated from the estimated one week ahead production schedule produced by the manufacturer, plus the supplier's own estimates based on their understanding and past experience. Essentially, this results in a randomly selected quantity, between a minimum and maximum level.

We propose several simple alternative rules. The first is to retain the variable timing of the production, but to schedule a quantity equal to the difference between existing stocks and the maximum observed requirement for the subassemblies between the variable weekly production times. This variable timing allows the supplier to retain flexibility in scheduling to accommodate variable demands they face from their other customers. The second rule is to schedule the production at a fixed time each week, and to schedule a quantity equal to the difference between existing stocks and the maximum observed weekly requirement. The third rule refines this further, with production scheduled at a fixed time twice each week and a similar rule for the production quantity. These rules use the information about parts demand that is implicit in the flow of kanbans signalling finishing requirements, plus overall information about observed maxima in the recent past. They reduce the impact of the variability that currently occurs between the three information flows, by ignoring the one week ahead estimate of requirements, which by experience is a poor estimate of actual requirements as indicated by kanban requests.

Results of these scheduling experiments are summarised in Table T1 (rdm, wk, and tw wk for random timing, fixed weekly timing, and fixed twice weekly timing respectively). The first proposed rule has eliminated the manufacturer's store and floor stockouts, and similar average stores levels to the base case. For the supplier, the average subassembly stockholding has decreased slightly, with a substantial decrease (about 32%) in the maximum stock. There are a similar (small) number of subassembly stockouts, but they last for a shorter time. The second rule, with a fixed time each week for intermediate production, has no manufacturer store and floor stockouts, and similar average stores levels to the base case. For the supplier, the average subassembly stockholding is decreased by 34%, and the maximum stockholding has decreased by 51%. No subassembly stockouts are recorded. With intermediate production scheduled twice-weekly, the gains are even more impressive. For the manufacturer, there are no recorded floor or store stockouts. For the supplier, there is a 56% reduction in the average subassembly stockholding and a massive 71% reduction in the maximum stockholding. No subassembly stockouts are noted.

This study does not purport to offer the best solution to this problem area of subassembly scheduling, but rather to highlight that alternatives are available. It demonstrates that it is feasible to accommodate the flexibility in the manufacturer's demand pattern without increasing stocks.

DISCUSSION

We investigated two important processes in the manufacturing logistics system, that of the parts flow process internal to a manufacturer or a supplier and that of the linkage between parts requirements at the manufacturer and parts production at the supplier. The linked production system has partial control by kanbans and partial control by MRP and estimated production requirements.

In terms of the operation of the system, we have shown that kanban numbers, and hence stockholdings, can be reduced without impacting the responsiveness of the manufacturer's system to the variable production demands for parts. Potential reductions of 25% in the manufacturer's stock holdings are available.

The supplier had experienced increases in their stockholding of subassemblies when the manufacturer switched to kanban requests for parts replenishment. It was proving difficult for the supplier to determine an appropriate number of subassemblies to produce each week. We demonstrate that simple-to-use scheduling rules for determining the quantity of subassemblies to produce can yield impressive savings both in average and maximum stockholding levels, without affecting the ability of the supplier to finish parts as requested by kanbans. These rules are easy for the supplier to implement. The performance we predict if the twice-weekly rule were adopted is a motivator for the supplier to consider ways to reduce the set-up times on the subassembly machine, as this is a major reason why they wish to produce subassemblies only once a week.

The study also highlights that the appropriate information flows for control are perhaps more important than the volume of information which is shared between the supplier and the manufacturer. Using the observed actual maximum usage figures to schedule production of subassemblies means that the generic production schedule, and its implicit parts requirement statement, which was often poorly matched to actual requirements, is no longer required. This simplifies the information handling task for the supplier, as they have one less piece of information to consider when developing their production schedules. Confused and inconsistent information flows between a manufacturer and a supplier impede performance for both parties.

We observe that system modelling using system dynamics works for the micro-level of operations. It easily allowed the mixed push and pull control systems to be modelled. The feedback features of information flowing in the reverse direction to materials was accommodated within the model without difficulty. The availability of the discrete capabilities in ithink! simplified parts of the modelling process. Because ithink! includes user-controllable random number generators, it was easy to model the variability inherent in the production system at the micro level.

Building this systems model assisted both the manufacturer and the supplier to gain a better understanding of the structure of the linked system within which they operated. They could gain an understanding of the significance of their actions, and experiment without disturbing their existing production systems.

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Appendix A1: IThink Model of Integrated Logistics System

	base avg	base min	base max	rdm avg	rdm min	rdm max	wk avg	wk min	wk max	tw wk a	tw wk n	tw wk x	factor
no. floor stockout	1.9	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.43
avg fl stockout time	2.5	0.0	37.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.43
avg manuf store	69.6	68.7	70.1	69.7	68.8	70.3	69.4	68.8	70.3	69.4	68.8	70.3	13
min manuf store	29.2	0.0	46.2	36.9	23.1	46.2	38.5	30.8	46.2	38.5	30.8	46.2	13
max manuf store	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	13
no. store stockout	1.9	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7
avg st stockout time	4.2	0.0	63.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.43
avg subass inventory	37.4	23.7	54.6	36.4	35.5	37.0	24.7	24.5	24.8	16.3	16.1	16.4	3484
max subass inventory	79.1	70.2	100.0	53.4	52.8	54.0	38.3	38.3	38.3	22.7	22.7	22.7	3484
min subass inventory	3.8	0.1	16.0	1.7	1.0	4.6	5.8	4.6	7.0	4.8	3.4	5.8	3484
no. subass stockout	21.0	0.0	100.0	11.4	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0	7
avg sub stockout time	34.1	0.0	100.0	27.6	0.0	74.2	0.0	0.0	0.0	0.0	0.0	0.0	9.43
avg subass assembled	97.9	97.0	100.0	95.0	93.8	96.5	95.9	95.2	96.7	48.0	47.5	48.3	1040

TABLE T1: NORMALISED % RESULTS - SCHEDULE RULES - KANBAN NOS.

(Schedule results based on average values for 5, 10, 15 tests, depending on number of sources of variation; kanban results for 6 tests.)

Kanban number	24 avg	24 min	24 max	20 avg	20 min	20 max	18 avg	18 min	18 max	factor
no. floor stockout	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	8.7	23
avg fl stockout time	0.0	0.0	0.0	0.0	0.0	0.0	10.1	0.0	25.0	14
avg manuf store	69.6	69.2	70.0	38.8	38.4	39.2	23.6	23.2	24.1	13
min manuf store	42.3	38.5	46.2	11.5	7.7	15.4	0.0	0.0	0.0	13
max manuf store	100.0	100.0	100.0	69.2	69.2	69.2	53.8	53.8	53.8	13
no. store stockout	0.0	0.0	0.0	0.0	0.0	0.0	97.8	95.7	100.0	23
avg st stockout time	0.0	0.0	0.0	0.0	0.0	0.0	15.0	13.4	16.9	14
avg subass inventory	43.9	30.8	53.1	44.7	31.6	53.1	46.0	32.8	53.5	3694
max subass inventory	84.3	66.2	94.4	85.1	66.2	95.5	87.8	67.4	100.0	3694
min subass inventory	5.2	0.6	11.2	6.0	0.9	11.2	7.3	0.9	12.2	3694
no. subass stockout	10.1	0.0	56.5	0.7	0.0	4.3	0.7	0.0	4.3	23
avg sub stockout time	29.8	0.0	100.0	13.1	0.0	78.6	8.3	0.0	50.0	14