Kanban Size and its Effect on JIT Production Systems

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1. INTRODUCTION

Integrated planning, formation, carrying out and controlling of tangible and with them connected information flows from the supplier to the company, inside the company and from the company to the supplier is very important part of the life of the company. Systems Just in Time (JIT) and KANBAN are helping to manage the manufacturing company that among others costs are minimised and the productivity is maximised, that 100% quality is ensured and the stock is as low as possible.

Very important thing is to set kanban sizes – it is one of the first decisions that users of kanban must address. This paper examines the effect of varying kanban size on the performance of JIT manufacturing systems. We analyse two types of JIT production systems using computer simulation models – the Pull-type and the Hybrid-type. The performance measures considered simultaneously are the fill rate, in-process inventory, and manufacturing lead time. Also parameters as a demand rate, processing time, and kanban size are taken into consideration. Single product and multi-products manufacturing environments are investigated.

The aims of this paper on JIT systems are:

- An investigation of the influence of kanban size on the performance of JIT manufacturing systems, including Pull and Hybrid systems.
- An examination of the effect of kanban size on the interaction of the fill rate and the manufacturing lead time in a JIT system.
- With reference to the above findings, to determine a feasible kanban size to optimize the performance of production in terms of fill rate and manufacturing lead time.

2. JUST-IN-TIME AND KANBAN

The American Production and Inventory Control Society (APICS) defines JIT as "In broad sense, an approach to achieving excellence in a manufacturing company based on the continuing elimination of waste (waste being considered as those things which do not add value to the product). In the narrow sense, JIT refers to the movement of material at the necessary place at the necessary time. The implication is that each operation is closely synchronized with the subsequent ones to make that possible".

JIT systems are designed to produce and deliver goods or services as needed, using minimal inventories. It is a logistics philosophy focused on reducing inefficiencies and unproductive time in the production process and is practiced by many manufacturing companies. JIT philosophy, first introduced by the Toyota Motor Co. around 30 years ago, has attracted much interest in its basic underlying concept of which provide only the necessary products, at the necessary time and in the necessary quantity (Lai, Lee, Ip, 2003).

Kanban system is one of the means of achieving JIT production. Kanban pull system model is developed to analyse the logistics policies of a company and understand the customer, competitors, and suppliers relationships. "Kanban" is the Japanese word with the meaning "a card". In JIT, it is connected with kanban signal, which usually comes from the customer order – the signal than flows backwards via each work centre. Each work-inprogress (WIP) container is attached with a kanban, specifying details of that particular WIP (product name, part code, card number, batch number, lot size, due date etc.)

Manufacturing systems controlled by kanbans are different from conventional methods of control owing to the existence of limited in-process inventory (ie. constraints on buffer capacity) between workstations, and the consequent station blocking. This can be viewed as the limited floor space or the limited number of containers that could be present at the workstation. Continuous process improvement is initiated when smaller buffer capacities expose new problems. However, kanbans cannot be implemented in every production process because the degree of usability of kanbans varies, depending on the production system (Ramanan, Rajendran, 2003).

It is commonly believed and it has been proven that kanban size is a critical factor in providing better customer service. Generally, a large kanban size implies a higher inventory level but a shorter lead time benefited by less frequent machine set-up time.

Toyota's equation for computing the optimal number *n* of kanbans required for production is:

$$n = \frac{d_{\mathrm{ave}}(t_{\mathrm{w}} + t_{\mathrm{pc}})(s)}{k}$$

Where d_{ave} means the average daily demand, t_w the waiting time, t_{pc} the processing time per container, *s* the safety factor, and *k* container size.

A balance must be achieved between kanban size, production volume and a product variety. This paper provides a proposal of a solution for choosing the kanban size in order to approach as close as possible to the 100% fill rate at a shortest manufacturing lead time.

Fig. 1 shows the mechanism of material and message flow in the Pull-type system. That means that station K withdraws materials from the previous station K-1. After completing the process on station K it is send to next station K+1 and at the same time the kanban card will be sending backward to the upstream station K-1. In other words, every station will not start the production process unless both a kanban signal and the relevant input material are present.

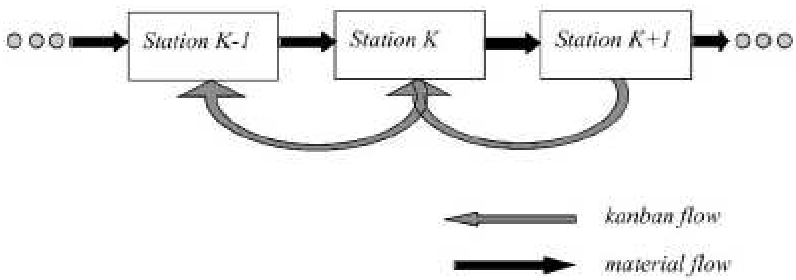

Fig.1. Mechanism of the material and message flow in a Pull-type manufacturing system

The Hybrid manufacturing system is a combination of the Push and Pull modes (fig.2). Sometimes it can be defined as a long-Pull manufacturing system. The difference from Pull-type is in the flow of the message. The kanban signal, instead of flowing backwards from station K to station K-1, flows from the last station directly back to the first station to actuate the production activities in station 1.

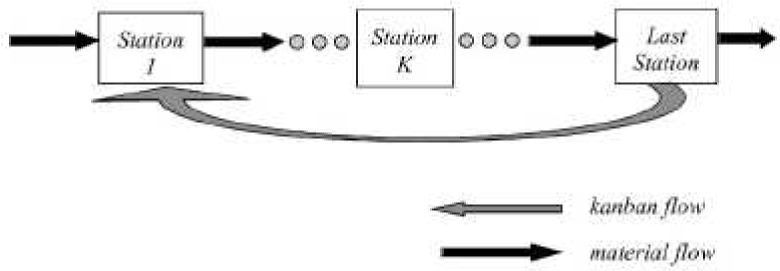

Fig.2. Mechanism of the material and message flow in a Hybrid-type manufacturing system

3. MEASURING OF PERFORMANCE

Four major criteria were used for the evaluation of the JIT system performance. Their aims and definitions are presented clearly as follows:

1) Unsatisfied order is defined as the difference between the actual number of units produced and the level of demand.
2) Manufacturing lead time is defined as the time between when the customer order is made and that when the order is completely satisfied.
3) In-process inventory is defined as the total number of work-in-process item in the system excluding the number of finished goods made.
4) Fill rate is defined as the percentage of the demand satisfied (Chan, 2000).

The testing of the effect of the kanban size on different types of JIT manufacturing systems were done according to two simulations models using the SIMPROCESS simulation package.

Experiments are carried out by varying the kanban size from 5 units to 100 units. Those are applied to following cases: 1. single product Pull-type manufacture, 2. single product Hybrid-type manufacture, and 3. multi-products Hybrid-type manufacture. All systems are modelled as a six-station flow line model.

4. RESULTS

4.1 Single Product

In the situation of single product system, all the machines only need to be set-up once, hence the set-up time is insignificant as compared to the total processing time – the ratio of production time to non-production time is large. Therefore, no matter how large or small is the batch to be processed, the time to complete the particular quantity of products will not be seriously influenced by the amount of machine set-up time.

4.1.1 Pull System

Fill rate – Fig.3 shows that the average fill rate decreases as the kanban size increases (processing time for a batch of large kanban is longer despite the insignificant machine set-up time). Obviously, there is a longer time for a large batch size, and a shorter time for a small batch size. Therefore, at the end of each data collection period, the probability for a batch of larger kanban size to be completed is lower.

In-process inventory – Fig.4 shows that the in-process inventory level increases with an increasing kanban size. The processing time is longer for a large kanban size, so the time for the batch to stay within the system will also be longer. Moreover, the time for each station to serve a full container becomes longer, so at the end of each data collection period it is easy to find a large percentage of the input material still working in process.

Manufacturing lead time – The behaviour of manufacturing lead time is quite similar to the inventory process (fig.5). Theoretically, no matter how large or how small is the kanban size, the available time for production is the same, because the machine set-up time is not significant in the case of single product manufacture. Practically small kanban size allows the system to move the WIP faster between machines. Consequently, finished goods are available in the form of small batches within a short time.

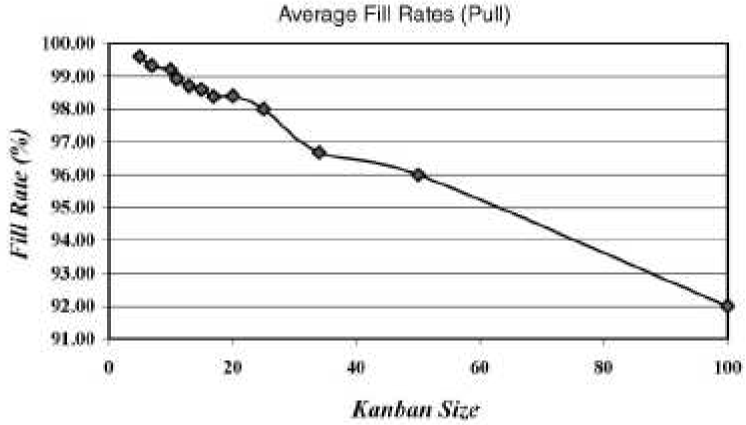

Fig.3. The effect of kanban size on the fill rate in a Pull system for a single product.

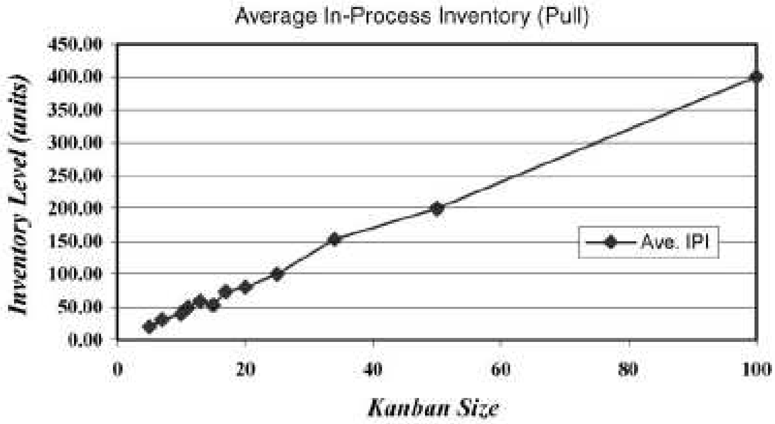

Fig.4. The effect of kanban size on the in-process inventory in a Pull system for a single product.

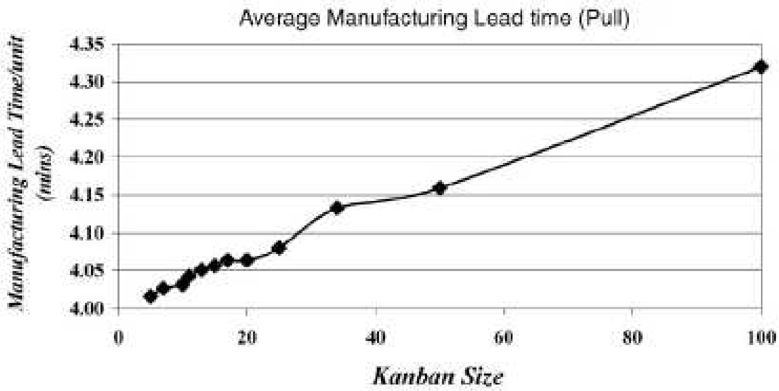

Fig.5. The effect of kanban size on manufacturing lead time in a Pull system for a single product.

4.1.2 Hybrid System

Fill rate – the trend in this case is very similar to a previous case in the Pull system. As fig. 6 shows the fill rate decreases as the kanban size increases. However, the service level of customer order satisfaction is found to be much lower than the performance of the Pull system (the fill rate is much lower for the same kanban size). With a kanban size of 50, the Pull system gives a fill rate with 96%, but the Hybrid system only achieves a fill rate of 50%. This is mainly because the machine utilizations in the first case are higher than those in second case in Hybrid system.

In-process inventory – Fig. 7 shows that the in-process inventory level increases with the kanban size (again similar to the Pull system). However, the maximum in-process inventory is found to be just over 250 units, which is smaller when compared to about 400 units in the Pull system (fig. 4). As was already explained before, more machines are fully utilized in the Pull system so therefore also here the difference is mainly due to the higher machine utilization in the Pull system.

Manufacturing lead time – again the behaviour (fig. 8) is in the same trend as in Pull system. Even in the case of the largest kanban size, the Pull system needs about 4.32 min to produce one unit of finished goods (fig. 5). However, fig. 8 shows that the highest value is about 16.9 min per unit. Therefore, on average, the manufacturing lead time is longer in the Hybrid system.

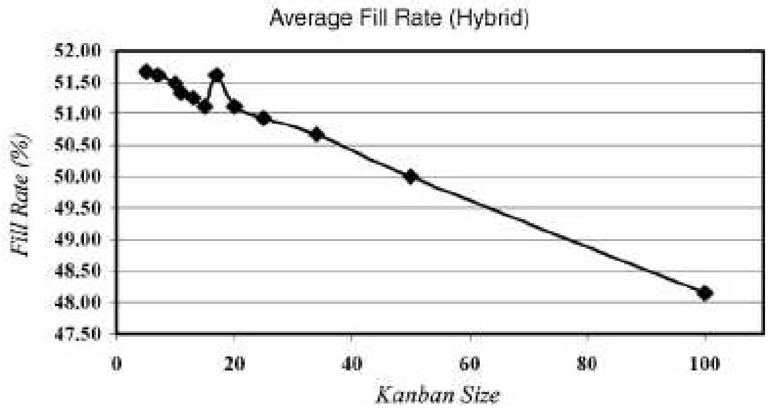

Fig.6. The effect of kanban size on the fill rate in a Hybrid system for a single product.

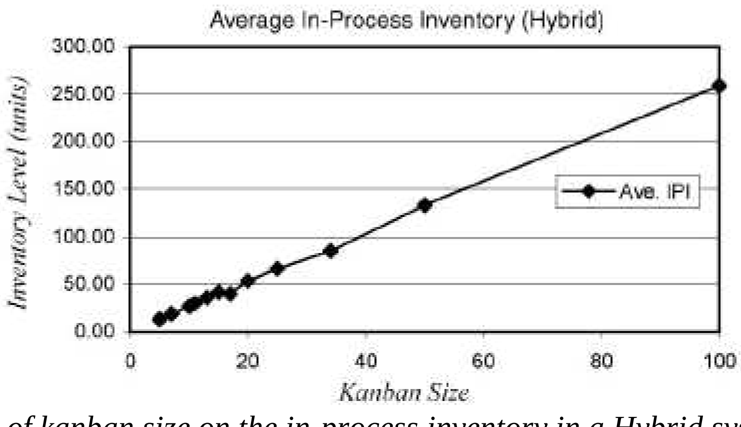

Fig.7. The effect of kanban size on the in-process inventory in a Hybrid system for a single product.

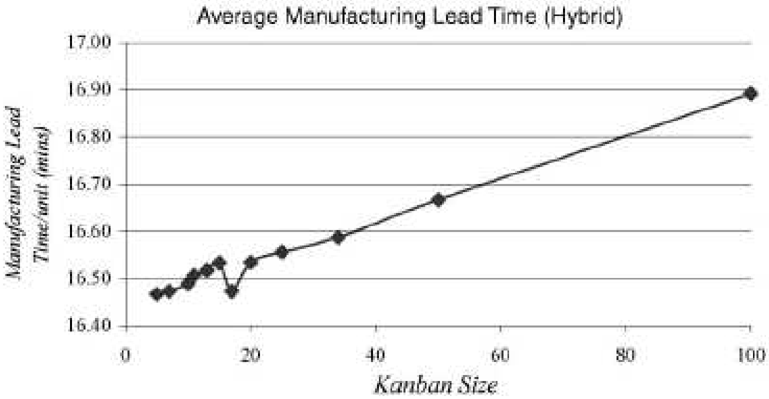

Fig.8. The effect of kanban size on manufacturing lead time in a Hybrid system for a single product.

4.2 Multi Product

4.2.1 Hybrid System

Under the situation of multi products manufacture, the time for set-up becomes important and significant when comparing to the processing time (the ratio of production time to non-production time varies significantly with different size if kanbans). A system with a smaller kanban size, which requires frequent machine set-up, would probably involve more waste of time in set-up.

Fill rate – fig. 9 presents the curve of fill rate increases exponentially, but eventually flattens out (as the size of kanbans increases the total machine set-up becomes increasingly less significant). When comparing fig. 9 and fig 6. there is an obvious difference. For the single product system, the machine set-up time is not a significant factor in the total processing time, therefore a large percentage of time is productive.

In-process inventory – fig. 10 presents products A, B and C going up as the kanban size increases. The reason is similar to that in the case of single product in the Pull and Hybrid systems.

Manufacturing lead time – with a small kanban size, the average manufacturing leading time is very high for the same demand level (fig. 11) – a large percentage of time is spent on non-productive activity (machines need to be set-up frequently).

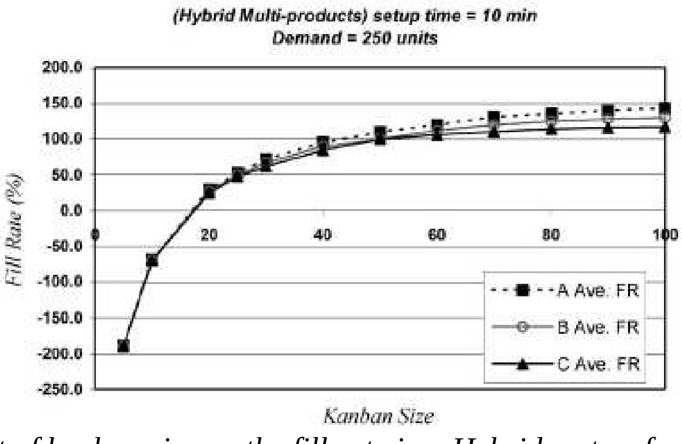

Fig.9. The effect of kanban size on the fill rate in a Hybrid system for multi-products.

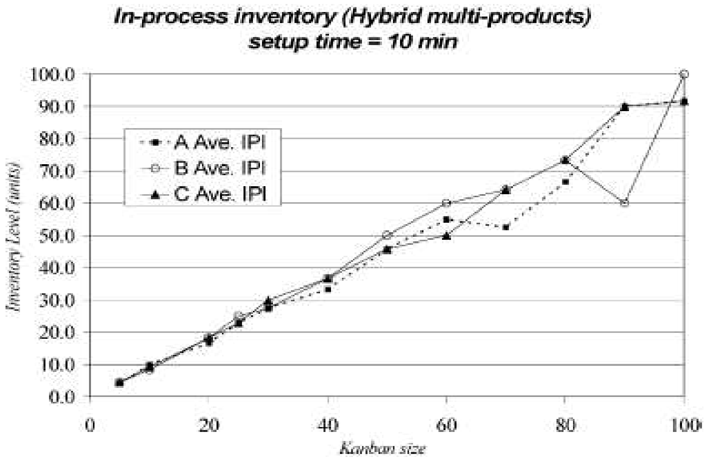

Fig.10. The effect of kanban size on the in-process inventory in a Hybrid system for multi-products.

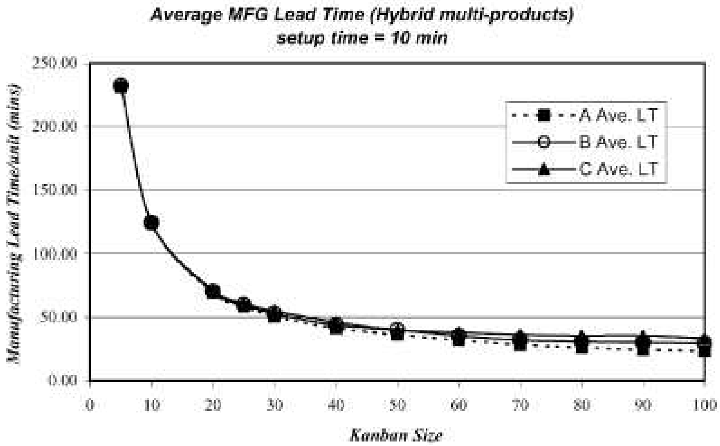

Fig.11. The effect of kanban size on the manufacturing lead time in a Hybrid system for multi-products.

4.3 Possible solutions

Machine set-up time can be reduced in many ways - for instance, introducing an automatic tool changing system for an NC machining centre, the elimination of special tooling via standardization, the upgrading of the quality of the workers (training), etc.

A benefit from reducing the kanban size is the reduction of the in-process inventory, which in fact frees the production facilities for developing new products. Shorter delivery time, and higher fill rate are the key competitive factors which lead to a better customer service.

Fig. 12 shows that the fill rate increases as the kanban size increases, however, a fill rate greater than 100% is not desirable. Excess inventories would be made for a stock than, which ties up resources and generate no immediate return from sales revenues. The feasible solution of kanban size is found to be around 65 units to fulfil a nearly complete satisfaction of customer order.

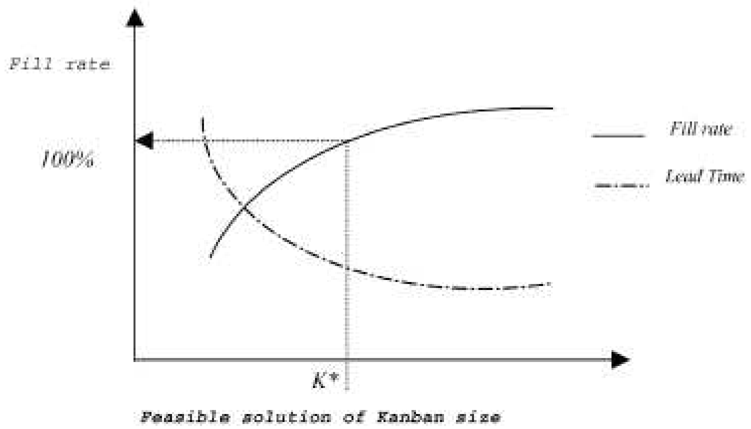

Fig.12. Optimal kanban size

5. CONCLUSION

This paper describes an approach to determine an optimal kanban size via simulation, with one of the objectives of being achieve 100% fill rate. In a single product manufacturing systems (Pull and Hybrid systems) the values of the performance measures differ significantly although the trends of the performance are similar.

The impact of increasing the kanban size on various performance measures are summarized as follows in tab.1 and tab.2:

Performance measures	Pull system (single product)	Hybrid system (single product)
Fill rate	Decrease	Decrease
In-process inventory	Increase	Increase
Manufacturing lead time	Increase	Increase

Tab.1. Changes when increasing the kanban size on various performance measures (single products)

Performance measures	Pull system (multi-product)
Fill rate	Increase
In-process inventory	Increase
Manufacturing lead time	Decrease

Tab.2. Changes when increasing the kanban size on various performance measures (multi-products)

According to above mentioned in the multi-products Hybrid systems, a larger kanban size often leads to the result of higher average fill rate, and lower average manufacturing lead time. Contrariwise, a smaller kanban size needs more frequent machine set-up, thus the non-productive time is increased significantly. In other words, for a larger kanban size situation, the productive time in normal working hours can be maximized, and the factory may probably benefit from savings such as the reduction of labour hours in overtime production, and energy. Nevertheless, a fill rate of over 100% is not desired. Therefore, the kanban size needs to be controlled within limits.

The main advantage of the smaller kanban size is the lower level of in-process inventory – inventory means money and smaller kanban size facilitates a faster movement of materials between stations. Therefore, the manufacturing resources are easily free from production, which may help in other manufacturing activities as Research and Development.

However, a 100% fill rate is not easily achievable when a smaller kanban size is implemented.

In reality, reducing the kanban size to achieve lower inventory level and at the same time retaining the full customer satisfaction it may not be easily implemented. Also there may be required capital investment in equipment; therefore, breakeven analysis should be carried out for detailed investigations of the possibility in terms of sales revenue. The decision of the kanban size should be made based on the trade-off between inventory level and better customer service.

REFERENCES

1. Chan, F. T. S.: Effect of kanban size on just-in-time manufacturing systems, Journal of Materials Processing Technology 116 (2001) 146-160
2. Chan, F. T. S., Tang, N. K. H.: Performance of Push, Pull, and Hybrid scheduling system in a flow shop manufacturing environment, Proceedings of the International Symposium on Advanced Manufacturing Processes Systems and Technologies (AMPST), University of Bradford, UK (1996), 27-36
3. Lai, C.L., Lee, W.B., Ip, W.H.: A study of system dynamics in just-in-time logistics, Journal of Materials Processing Technology 138 (2003) 265-269
4. Ramanan, G. V., Rajendran, C.: Scheduling in Kanban-Controlled Flowshops to Minimise the Makespan of Containers, The International Journal of Advanced Manufacturing Technology (2003) 21:348-358
5. Schonberger, R. J., Knod, E. M. Jr.: Operations Management, Continuous Improvement, Irwin (1994)

CONTENTS

1. INTRODUCTION **1**

2. JUST-IN-TIME AND KANBAN **1**

3. MEASURING OF PERFORMANCE **3**

4. RESULTS **3**

4.1 SINGLE PRODUCT 3

4.1.1 Pull System *3*

4.1.2 Hybrid System *4*

4.2 MULTI PRODUCT 6

4.2.1 Hybrid System *6*

4.3 POSSIBLE SOLUTIONS 7

5. CONCLUSION **8**

REFERENCES **9**

CONTENTS **9**