



Review Article – Computer Science Engineering

A Review of the Implementation of JIT Algorithms and Models in Production Systems

Chukwuedozie N. Ezema^{1*}, Eric C. Okafor², and Inyama C Hyacinth¹

¹Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

²Department of Computer Engineering, Enugu State University of Science & Technology, Enugu State, Nigeria

Abstract

Intense competition in today's economy, the shrinking life cycles of products, and the heightening expectations of customers have forced business enterprises to focus their attention on correctly arranging and controlling their production and supply chain systems. Thus, manufacturing firms/industries adopt JIT techniques to enjoy competitive advantage. In this paper, a literature review is presented to show the important applications of JIT Algorithms and Models in Production Systems. The purpose of this step is to review the results obtained from the implementation and to provide the practical recommendations for further improvement. This will help reveal practical issues encountered in the implementation. All these issues should become main concerns if the manufacturing Plant wants to get maximum benefits from the JIT implementation. This study bridged a research gap by identifying a framework for re-design of manufacturing systems into practical optimum Just-In-Time systems. The conventional JIT approach is mostly applicable to static production systems and the dynamic production systems require a more practical integrated JIT approach.

Key words: Just-in-Time, Demand Pull System, Production Systems, Network Map Algorithm

Introduction

Abegglen and Stalk [1] revealed that the JIT philosophy revolves around four major points: the elimination of activities that do not add value to a product or service; a commitment to a high level of quality; a commitment to continuous improvement in the efficiency of an activity; and an emphasis on simplification and increased visibility to identify activities that do not add value. With these four major aspects in mind, different techniques have been developed when adopting JIT methods in different types of industries. JIT may be applied in both the purchasing and the production areas. The purchasing applications of JIT are broader, in

terms of the types of organizations which may benefit from its adoption, than its production applications. Any company may use JIT purchasing techniques by developing close relationships with their various suppliers. One of the most popular JIT production methods used is known as the Kanban system.

JIT Concepts and Applications

[2] used a Just-in-time (JIT) manufacturing methodology that seeks to make Nissan Motor Company production processes more efficient. In his context, efficiency means that wastes within the process have been eliminated. He contended that JIT supposes that a company's production process is one that *pulls* raw materials through its process, as opposed to *pushing* raw materials through its process, as a traditional production process would.

As analyzed in his work, Figure 1, shows a JIT production process, one which pulls raw materials through its processes.

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*Corresponding Author

Chukwuedozie N. Ezema, *Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*

Figure 1: Just-in-Time Demand Pull System [1, 2]

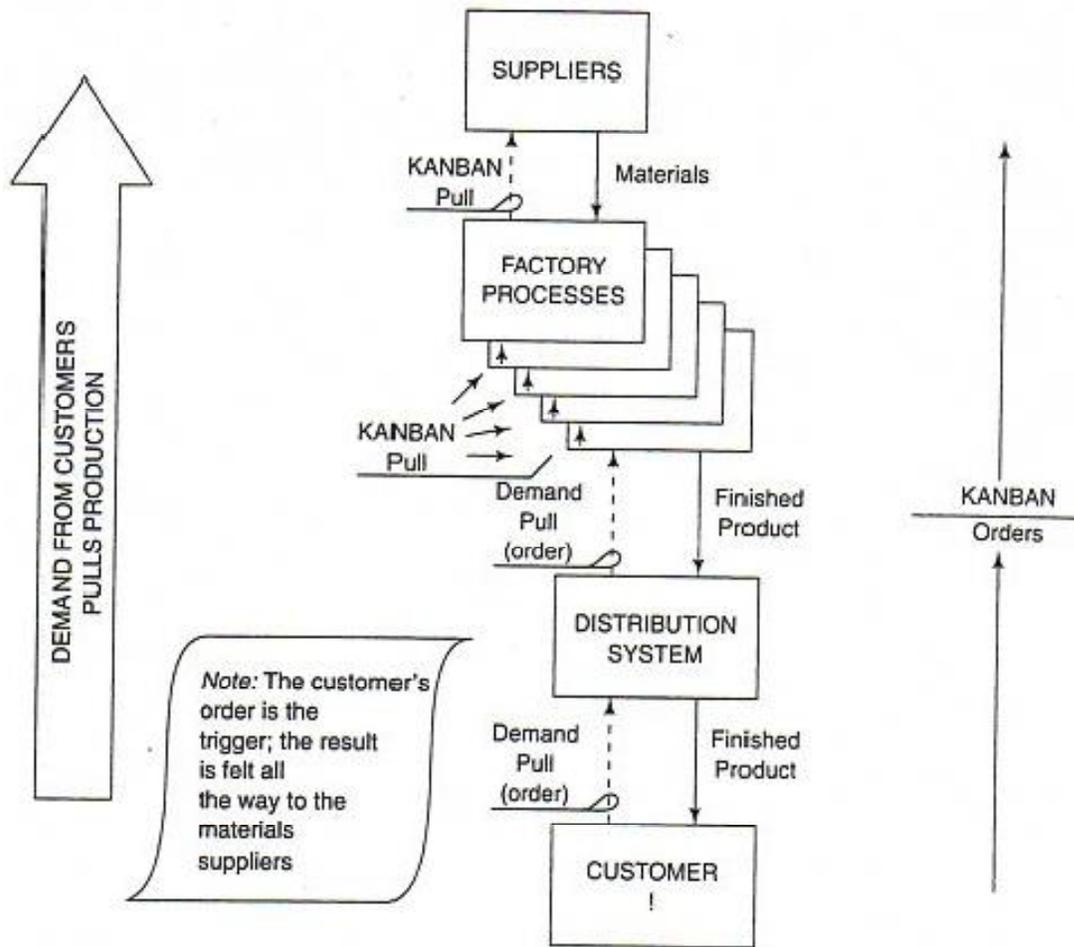
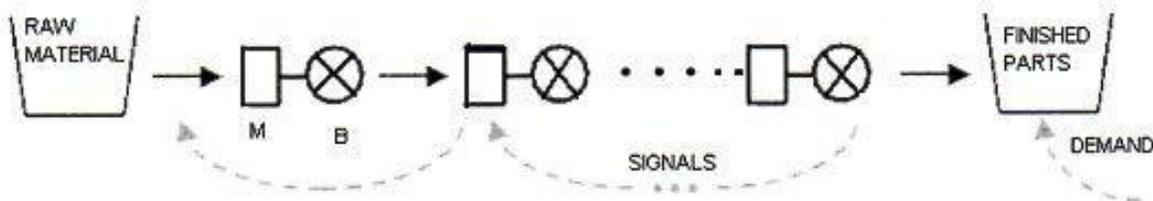


Figure 2: Pure pull or JIT system [3]



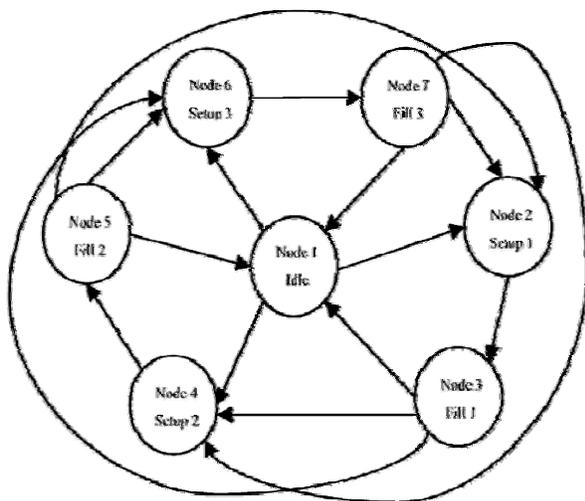
As one can see in Figure 1, the production process is put into motion by actual customer demand. By knowing actual customer demand before the process begins, the company definitively identifies exactly what products to produce and in what quantities to produce them. At this point, the orders for products and raw materials are passed upstream, typically with the usage of kanbans (Figure 2). This allows each

preceding operation to know exactly which product to produce and in what quantity to produce it, allowing them to produce no more than the amount required by the downstream entity requesting that production. The findings of his research reveal that the implementation of JIT manufacturing offers many benefits not only for a company, but for its employees and customers, as well. JIT makes a company's manufacturing

processes more flexible, as JIT establishes a production environment which functions by matching actual demand. However, his study was limited to a multi-stage single product system.

[4] conducted a study on “production sequencing and stability analysis of a just-in-time system with sequence dependent setups.” The study investigated an approach for determining stability and an approach for mixed product sequencing in production systems with sequence dependent setups and buffer thresholds. Buffer thresholds signal replenishment of a given buffer. [5] developed a product sequencing algorithm that determines a product sequence for a production system based on system parameters – setup times, buffer levels, usage rates, production rates, etc.

Figure 3: Network Map Algorithm of Three-Product System – With and Without Idle



The algorithm selects a product by evaluating the goodness of each product that has reached the replenishment threshold at the current time. The algorithm also incorporates a lookahead function that calculates the goodness for some time interval into the future. The lookahead function considers all branches of the tree of potential sequences to prevent the sequence from travelling down a dead-end branch in which the system will be unable to avoid a depleted buffer. The sequencing algorithm allows the user to weight the five terms of the goodness equations (current and lookahead) to control the behavior of the sequence.

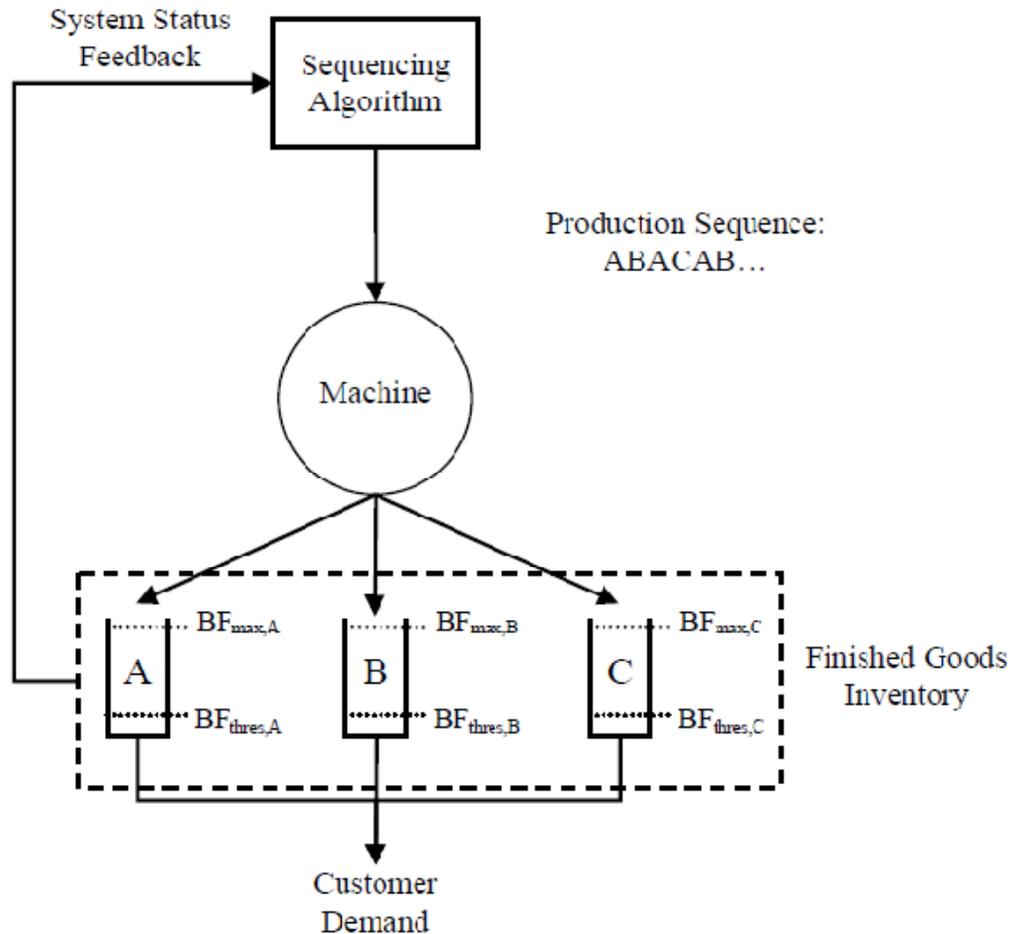
In this network, all product sequences may pass through the idle node prior to being

replenished or a product can wait in a queue to enter setup directly after replenishment of the previous product. All weighting factors are set equal to 0.2. The algorithm cycles through the network (Figure 3) approximately twelve times to determine the stable regions for the system. The results from the algorithm for this arc-node network still contain the same regions as the previous system, but these regions are now segmented into smaller regions. The output also contains the additional regions for the arcs that skip idle.

[6] explored product sequencing method intended to be implemented for a JIT factory floor as an on-line production sequencing system. The Production System Model adopted in his work is one in which there are multiple products with potentially different production rates and usage rates and significant sequence dependent setups between products. The production system is assumed to be a single stage system that can have idle time, see Figure 4. The system functions such that customer orders come into a “black box” of the sequencing algorithm as well as product information (current production conditions, buffer size and fullness levels, production and usage rates, setup costs, etc.). The algorithm processes the information and outputs a product to be produced next, which is passed to the production stage. The algorithm is intended to be updated and run after each product refill, where the sequence is based on real-time feedback of the system parameters. An alternative use is to run the algorithm to generate a short sequence of products at a given time interval, such as sequencing a day’s worth of production determined each morning based on the current state of the production system.

The algorithm models a production system in which production occurs in batches, the batch size is the quantity of products required to fully replenish the buffer to a full level. When the product batch is completed, it is stored in Finished Goods Inventory (FGI) until a customer order is received and the required number of products is removed from FGI to meet the order. Buffer thresholds ($BF_{threshold,i}$) are defined for each product to signal the algorithm that the given product needs to be replenished.

Figure 4: Production System Model



Only products at or below the buffer threshold are considered by the algorithm and if all products are above the buffer thresholds, the production system is idle. However, the present study will replicate a lean system that only produces when customer demand is present.

[7] in a study titled “Kanban, Zips and Cost accounting: a case study” observed that “Kanban,” the Japanese word for card originated from the use of cards to operate a pull system of material control that linked all supplying operations to a final assembly line. The study using survey research methodology found that the ultimate goal of this system is the conversion of raw materials into finished products with lead time equal to processing time. Kanban attempts to achieve this goal by concentrating on the following areas: reduction of inventory and lot sizes; reduction of setup costs; elimination of queues; providing effective maintenance programs to eliminate

production defects entirely (improving quality); reducing lead times; making vendors part of the team in terms of planning needs and delivery times; and minimizing employee turnover through consensus management [8]. A comparison of these factors with the typical American manufacturing philosophy reveals why JIT implementation in the U.S. has been a slow process. Findings from [9] reveal that inventory is regarded as an asset in an ordinary manufacturing plant, and the plant strives to produce more, just in case, any manufacturing problems arise. Formulas are used to determine optimum lot sizes based on the trade-off between cost of inventories and the cost of setup, and no attempts are made to reduce these lots. Setups costs are not considered very important, as usually the plant's main goal is to maximize output. Investment in queues is necessary since queues permit succeeding operations to continue in the event of a problem

with the feeding operations. Vendors are considered adversaries, and competition between them is encouraged. Defective parts are tolerated, and methods are developed for forecasting future production of scrap. Equipment maintenance is done as required, and it is not critical because queues are available. Again, in terms of lead times, more not less is considered better.

Finally, workers do not have much input regarding new systems installed. However, they are evaluated based on those new systems. It is evident from the study that most of the goals of a Kanban (JIT) system contradict the traditional manufacturing or management philosophies of a typical manufacturing company. Therefore, implementation of Kanban or other JIT processes involves significant changes in the way companies are used to operating. Any successful implementation of JIT must involve a total commitment of the firm's top management as well as of its employees. The implementation of JIT in the purchasing area involves the availability of materials from suppliers just when they are needed by the company. Under this type of environment, a company must develop a very close relationship with its vendors in order for them to deliver quality parts on time.

[10] employed multifactor analysis on a sample of 50 companies in Taiwan and found that companies using JIT purchasing, usually select a small group of vendors as their suppliers, and try to arrange long term commitment contracts with these vendors. The vendors must become part of the manufacturing team, and they are essential for a smooth production flow. JIT purchasing techniques are a must for companies that are trying to implement JIT production. If the materials needed to produce a product are not available, the entire production process will be affected. Some companies using JIT purchasing have developed rating systems for the selection and evaluation of their vendors.

The study by [11] revealed a vendor rating system based on ten performance factors developed by a company in their study. The ten factors were: dollar cost, quality costs, terms of sale, meeting product specification, meeting product expectations, quality assurance, delivery quality, lead time, administrative accuracy, and

product support. Weights were determined for each of these factors, and the company's suppliers were rated based on their performance. The company sponsored a vendor day, in which it presented awards to its top performing vendors. The vendors' reaction to the company's system was generally positive. They viewed the company as being on top of things, and it was an incentive for them to try to improve their quality and service to the company. As the company became more aware of the type of service required from their vendors a modified rating system was developed. Although their system involved several judgment calls, it was a quantitative system that any company may use when evaluating vendor performance.

[12] found that the automobile industry has also been heavily involved in the JIT purchasing area, and that both General Motors and Ford have sophisticated systems in place for evaluating and selecting potential suppliers. Additionally the study listed several factors that should be considered when choosing JIT suppliers: 1: more is not necessarily better, and better is not necessarily cheaper -when purchasing supplies management must consider all of the cost involved, not just the lowest price per unit (cost of poor quality involves downtime, etc.); 2: a selection team must be chosen to evaluate and select suppliers -this team should involve personnel from the various areas of the firm that will be affected by the suppliers' performance; 3: suppliers may be used as designers by aiding in the improvement of the company's existing products and in the development of new product lines; 4: quality standards should be established up front; 5: price, of course, is important, and it must be negotiated between the company and the suppliers; 6: suppliers must be motivated to provide good service to their customers.

Although all of the above may not be necessary to implement JIT purchasing, they provide some general guidelines for companies to follow when trying to establish solid relationships with their vendors. Supplier performance in a JIT environment is critical, and the time spent in the selection process will have positive long-term effects to the companies' future operations.

Several U.S. companies have been using JIT techniques since the mid-1980's. The discussion

that follows will describe three very different types of organizations that have adopted JIT processes in their operations. These three companies provide examples of the diversity of environments to which JIT may be applied. The first company discussed will be Hewlett-Packard, a leader in the computer industry. The second is Valmont/ALS, a steel fabricator in Brenham, Texas, and the third is a small manufacturing company named Norfield Manufacturing Co. JIT applications will be discussed in a large company setting, a job-shop type environment, and from the perspective of a small closely-held manufacturing company. The discussion will also include some of the cost accounting changes made by these companies because of JIT.

[13] developed one of the very first JIT simulation models with kanban by SLAM. Their paper evaluated overtime requirements for changes in the number of kanban included in a JIT system, processing time variance and demand levels. They used SLAM II language to model the flow of two kanban and a multiline, multistage production process using Kanban in a pull JIT system. [4, 15] assessed some features of a JIT system for a welding assembly line. They discuss the techniques used to develop the JIT models through GPSS/H simulation language. [14] discuss that the application of JIT techniques in batch chemical processing environment under variable demand imposes significant capacity management problem. Furthermore, the spreadsheet simulation techniques are recommended for JIT modeling. They present a case study to clarify the links between service levels and resource utilization, which can help management decisions regarding timing, levels of stocks and sizing facilities.

[15] presented a case study of a simulation modeling approach in the design and analysis of a proposed JIT for a chemical company. The simulation approach was used to compare two cell designs and to estimate utilization levels for operators and material handlers under the new JIT system. [16] argue that computer simulation is an ideal tool for implementation of JIT system due to its wide range of activities. They have developed a software package, which simulates JIT manufacturing system.

[17] proposed an approach for helping companies in the selection of the most appropriate synchronization approach through simulation models. The models are based on three synchronization approach, namely, JIT, just-in-case and drum-buffer-rop. [18] presents description of 26 JIT implementations in US and Asia. Three JIT ratio analyses are discussed: (1) lead time to work content, (2) process speed to sales rate and (3) number of pieces to number of workstations. [19] discusses the development of a simulation model of a workshop that is line balanced and operating in JIT fashion. The simulation model takes into account the theory of constraints via Microsoft Excel by considering m parts processed through n work centers.

[20] investigated the impacts of different market demand patterns on system performance of a plant that implements either JIT or theory of constraint (TOC) in Taiwan. The authors used SIMAN to develop simulation models of a plastic-mold injection plant. The system performance was considered in terms of average work in progress (WIP) inventories and throughput time. They report that both philosophies can have significant improvements on system performance without large investment of capitals. The JIT systems have been advantageous to small, medium, and large production systems in Korea [21]. The traditional JIT system applied to static production systems have the advantages such as reduced inventories, etc. In fact, the adaptation of JIT system to dynamic production systems is a difficult task because of its sensitivity to production factors. The dynamic production systems deal with high variability of demands, frequent and random machine breakdown, variable defect rates and high absence or separation rates of personnel (multitasking, etc.). They developed JIT production models that are indifferent to production factors and identified the optimal model that reflects the production circumstance of the Korean industries. Then, computer simulation was used to test selected models for the susceptibility of the production factors.

[22] developed a simulation model for kanban based scheduling in a multistage and multiproduct system. They demonstrated that under a set of

operational conditions, the proposed simulation model could obtain a more improved JIT system.

[23] analyzed the effects of different maintenance policies and machine unreliability on JIT systems. The Taguchi method together with computer simulation was used to evaluate the effects and collect the required data. [24] discussed the potential use of computer simulation and operations research techniques for design and analysis of JIT operation of a warehouse. [25] described the JIT simulation model of a production line and discuss the possibility of JIT implementation.

[26] developed a framework for design and analysis of a JIT manufacturing system based on scheduling, material handling and simulation techniques. [1, 23, 22] have developed computer simulation models for analysis and assessment of JIT production systems.

There are other studies, which highlight the importance of JIT simulation modeling [12, 25]. Simulation Optimizes JIT System Design [21, 26]. [27] presented a non-sequential JIT simulation model for batches of parts to be routed between operations within the same facility. [28] presented a computer simulation of the performance of a number of scheduling rules under different JIT scenarios. [28] reported the effects of Gamma, Log Normal and Truncated Normal process times on a hypothetical assembly line with one kanban. The preceding studies highlight the importance of dynamic behavior of production systems with respect to JIT design. In addition, variation in production times (at each stage) has the potential of creating idle time for machines and increasing overtime costs to meet production schedules. This is why design and implementation of a JIT system may last up to several years. It is concluded that conventional (theoretical) JIT does not fit most dynamic systems and is more applicable to static systems.

Furthermore, design and implementation of theoretical JIT philosophy may not be possible for most dynamic systems due to their unique limitations and constraints. Therefore, a more applicable JIT design approach compatible with the limitations of dynamic systems is required. The preceding pros and cons of JIT demands powerful tools for design and assessment of the

dynamic systems into JIT before actual deployment. In fact, there are certain difficulties in design and implementation of JIT that could be overcome by integration of computer simulation and analysis of variance (ANOVA).

Several articles have been written describing the various JIT applications that Hewlett-Packard (H-P) has adopted over the past several years. One more major result for the study was HPD began developing the Kanban manufacturing system for the production of personal mass storage units {disk drives}. The production process was set up in a U-shape, passing one unit at a time with no buffer stock. "If the employee's Kanban out-square is filled, he or she may either complete the unit being worked on, sit idle, or help a downstream employee; once the unit an employee is working on is completed, the employee cannot work on another unit, [13, 29]. If a problem occurred during production, the problem was immediately corrected before the production process continued. Therefore, inventories of defective parts were eliminated. Under this system, employees were encouraged to perform quality work and improve productivity. The Kanban system implemented also included JIT purchasing. HPD managed to reduce total inventory supply from 2.8 months to 1.3 months within a 6- month period, and only 24 vendors were supplying 100 parts "just- in-time". The company managed a 48% reduction in the number of vendors; a 30% reduction in the number of raw material inspections; and total factory output tripled over a period of eight months.

HPD's cost accounting system was previously a work-order- based job-cost system. Since the arrival of the Kanban system, HPD has eliminated the use of work orders, and it no longer uses a WIP account. Under the Kanban system, specific unit costs are de-emphasized, and the accounting system used combines some of the elements of process costing, in the use of standard material cost and in assigning overhead to production processes, but many of the traditional process and job order cost accounts have been eliminated. The company has created a new account, called the raw-and-in-process (RIP) inventory account, which combines raw materials inventory and work in process into one account. Since RIP should be insignificant under a JIT system, HPD uses the backflush accounting method for recording its

manufacturing costs (the backflush method will be discussed in more detail when the accounting implications of JIT are examined). A major change in cost accounting at HPD involved the treatment of direct labor costs. Because of the small percentage of total product costs attributed to direct labor, cost accountants decided not to charge direct labor to each manufacturing unit. Direct labor costs are still analyzed and tracked, but not at the same level of detail as was done in the past. The division has also changed its method of allocating overhead because HPD realized that about half of its overhead costs were related to materials procurement and manufacturing support. As far as inventory control, HPD's primary goal is to minimize their investment in inventory. Physical inventories of finished goods are now performed on a monthly basis; the RIP inventory account is verified using an ABC classification method. "A" parts, which account for 90% of the total dollars, are counted twice a month, while "c" parts are counted every two months. HPD also changed the methods used to compute its variances.

In another work, [11, 30], clarified that the division now recognizes variances only at the point of purchase and production, and labor efficiency variances are no longer calculated as labor hours are incurred. Variances are computed combining labor and overhead costs. Because of this cost aggregation, some of the resulting variances are producing misleading information. HPD may be able to improve its variance analysis by separating the fixed and variable components of direct labor and overhead, and computing the variances for fixed and variable costs separately. Through the use of Kanban system, HPD simplified its accounting as well as its inventory procedures. The plant showed a decrease in direct material costs per unit, but no change in labor and overhead costs due to additional investments in these areas. There was also an increase in the number of units produced during this period, but a reduction in the amount of storage space, indicating faster turnover of inventory. Because of the Kanban philosophy, HPD spent time and money helping employees develop a team attitude. Employees were trained and educated on the JIT philosophy, and team meetings were held regularly to deal with topics such as stress, quality

and line balancing. Overall, it appears that HPD has been successful in the implementation of a Kanban (JIT) system, and the division is pleased with the accomplished results thus far.

Although, JIT processes seem best suited for companies dealing with repetitive manufacturing, they have been effective in job-shop operations. The study by [31] describes how Valmont/ ALS, a job-shop steel fabricator in Brenham, Texas, adopted a modified form of JIT in order to improve its operations during down times in the steel industry. The company attempted to produce only to customer order, and to reduce the amount of time it took to produce an order. The company first focused on determining their main constraints. Additionally, they identified two external constraints: a marketing constraint (the company could produce more than it could sell), and the location of the engineering function. The bottlenecks at the plant occurred primarily at the weld assembly area. The company adopted a new system to operate the job-shop, which they considered a modified Kanban (JIT) system, in which inventory would be pulled through the shop at a rate dictated by their constraints. Their prior Material Resource Planning (MRP) system pushed inventory through the shop without acknowledging the constraints. The company encountered two major problems in the implementation. First, the plant's engineering and marketing departments reported directly to the home office, and these two groups were not aware of the production changes being made at the plant. Therefore, training had to be expanded to the organization as a whole. Secondly, the plant had to determine how to schedule the shop in the most efficient manner. Again, this involved some changes to the company's MRP system. Since the company could not afford a new computer system, modifications were made to the current system to schedule job-shop operations on a daily basis. The company was able to reduce its inventory, reduce lead times, and deliver products to customers on time. Overall, the company experienced positive results from the implementation of the modified JIT process, and the company is constantly improving the system's performance.

[32] presented another example for the Norfield Manufacturing Co., which is a small

closely-held business employing about 60 production workers in 1988. It illustrates JIT applications in a small company environment. The company manufactures pre-hung doors, and the machinery used to manufacture these doors. The company continued to expand, but it still maintained its inventory accounting under the periodic method. "Management recognized the need for a standard cost system to track costs of inputs for production. The president of the company was aware of the production advantages of world class manufacturing, and management decided to look at methods such as that being used by Hewlett-Packard, to improve their production process and their accounting systems.

The company identified five goals in attempting to improve its production operations:

1. "Engage employee involvement, not just participation;
2. Implement just-in-time production techniques;
3. Institute total quality control;
4. Operationalize total preventive maintenance; and
5. Work toward continual rapid improvement."

Through achievement of these goals, the company hoped to provide a higher quality product that would reach customers quicker at a lower cost.

The first changes made by the employees, were the redesign of the shop floor layout and the collection of accounting data on the job floor. Once employee involvement was established, the next step was the implementation of just-in-time production. In this area, Norfield was able to reduce throughput time; it was able to reduce inventory as well as handling and storage costs; and it was able to redesign its raw materials inventory procedures by focusing on a single supplier for its primary material –steel. The three additional goals were achieved as the JIT process continued to evolve.

The major findings in [32] were that: first, accountants have been accused on hindering the implementation of JIT processes due to the following reasons:

- 1- "Costing systems foster anti-JIT attitudes,
- 2- Accountants don't want their systems messed up,

3- Accounting costs mislead about the benefits of JIT,

4- Accountants cannot (or at least do not) provide some of the information needed for the control of a JIT system, but they do waste resources providing information which is of no use, and

5- Where JIT involves capital expenditures; capital appraisal methods ignore many of the benefits.

Second, under current costing systems, fixed overhead recovery is based on machine or direct labor hours. This allocation encourages the company to produce as much as possible in order to recover all of its overhead. Also, manufacturing plants tend to organize production processes into cost centers. These cost centers strive to increase their own production goals, and they are not concerned if defective items are passed on to other departments. Both of these factors go against JIT goals. JIT systems also attempt to simplify accounting procedures. Third, one of the ways in which this has been accomplished is through the elimination of work orders. Accountants previously used these documents as one of their main sources of data. Forth, employees become more flexible under JIT; they may even perform indirect labor functions such as machine maintenance. Therefore, time sheets and detailed time reporting as well as incentives based on individual performances may need to be abandoned. Since JIT processes units based on demand, certain workstations may be idle during the day thereby increasing labor cost per unit of output, and decreasing the number of machine hours and the amount of overhead recoveries. JIT involves a heavy emphasis on reducing WIP. Information on how much stock is held, and where it is located is very important in a JIT system. JIT also places significant emphasis on the quality of products, but accountants does not have measures in place to compute the financial benefits derived from improved product quality. An excessive amount of time is spent measuring labor costs which are a declining part of total product costs. Since most of the benefits of JIT appear gradually, are longer term, and are hard to identify, it may be difficult to measure how well a JIT system is performing. As explained above, accountants have a lot of obstacles to overcome when adapting to

JIT techniques. Accountants should be involved in the implementation from the beginning, and they should make an effort to understand the new production system and how it functions, and what accounting changes need to be made to better cope with the new environment.

Adopting JIT in manufacturing companies involves significant changes in management's thinking and overall goals. Implementation of JIT requires many manufacturing changes, and cost accounting information previously required by management may no longer be relevant. Although accounting is not considered a high priority when converting to a JIT process, management must realize that cost accounting information needed in a JIT environment may be different than that required under their old production process. Cost accountants provide information to management to help them in the decision making process. Cost accountants must change their reporting methods to comply with the requirements of the new JIT system.

[33] addressed some of the cost accounting implications associated with JIT. The authors examine the effects of JIT purchasing separately from JIT production. As was previously discussed, these two areas are not necessarily dependent on one another. JIT purchasing may be used without JIT production. However, JIT purchasing is very important if a company has implemented JIT production. If a company is using JIT purchasing, the authors suggest that its cost accounting system may be affected in one or more of the following ways:

- 1- Increase in the direct traceability of costs -under JIT, facilities may be used for material handling of a single product, thereby making the facility cost a direct cost.
- 2- Changes in the cost pools used to accumulate cost - generally, there is a reduction in the number of cost pools under JIT.
- 3- Changes in the bases used to allocate indirect costs to production departments -dollar value of materials or number of deliveries may be used to allocate indirect costs.
- 4- Reduces the emphasis on individual purchase price variance information -price variances are not

as significant under a JIT system. JIT is more concerned with the total cost of operations, and with providing good quality products.

Discount prices may be obtained by entering long-term commitment contracts with suppliers. 5- Reduces the frequency of reporting of purchase deliveries in the internal accounting system -use of the backflush costing system. When a company uses JIT production, the authors believe that cost accounting is affected in one or more of the following ways:

- 1- Increase in the direct traceability of costs - again in a JIT system, activities that were previously classified as indirect will become direct. For example, plant maintenance and setups previously classified as indirect labor will now be performed by the production line workers.
- 2- Elimination of cost pools for several activities classified as indirect -JIT eliminates activities that do not add value.
- 3- Decrease in the emphasis placed on individual labor and overhead variances -some firms have eliminated labor and overhead variances. However, when variances are still utilized, the emphasis of the analysis is at the plant level focusing on trends that may be occurring in the production process.
- 4- Decrease in the amount of detailed information recorded in work tickets -use of the backflush costing system.
- 5- Decrease in the level of detailed information recorded about labor cost -JIT philosophy emphasizes teams' not individual workers.

The above lists suggest some of the cost accounting changes companies involved in JIT purchasing or production should consider. As is evident from above, some significant changes may be necessary to conform to the JIT procedures. However, most of the suggestions involve simplification to the current cost accounting system in place. Generally, there has been a concern in that accounting systems are too financial reporting oriented, and that they neglect internal reporting needs. Internal accounting systems, even before the adoption of JIT, are not providing management with relevant information

to be used for proper decision making. The backflush costing system described above was criticized in an article published by [34]. The article examined the problems faced by Hewlett-Packard when applying the backflush cost accounting system after the implementation of JIT. The authors believe that the backflush costing system does not provide management with all of the information needed for decision making. This was evident from the need to perform physical inventory counts at H-P in order to keep track of its raw materials and finished goods inventory.

As Calvasina et al. stated

“The need for this physical count system raises questions about the company's great advance in its accounting system.”

Use of the ABC method to classify materials indicates another flaw in the system, as under JIT, items are considered equally crucial regardless of dollar value. Another problem associated with the backflush system is that it eliminates the calculation of equivalent units of production (EUP). Additionally, the authors suggest, that under a JIT system, in order to obtain an accurate evaluation of production achievements, EUP must be calculated on the first-in first-out (FIFO) basis. Under the backflush system, entries are made only when the materials are transferred out, and any materials remaining in WIP are ignored. The article also recommends that cost accountants continue using standard costs in their planning process.

According to the authors, a good repetitive manufacturing accounting system should focus on the production process as events and transactions occur. The first entry, under their proposed method, will also be made when materials are purchased. However, materials will be charged directly to the WIP account, and any price variances will be recorded at this time. EUP for raw materials will also be calculated for the appropriate period and recorded. The same basic ideas apply when recording direct labor and overhead costs. When the goods are transferred to inventory or when the goods are sold, no variance will be recorded, and the goods will be transferred out at their standard cost.

A major criticism of the backflush system is that it records transactions only after the fact, and it does not track events or costs through the production process. This is why Hewlett-Packard is forced to take physical counts. The JIT philosophy attempts to eliminate wasting time on nonvalue-adding activities. The taking of physical inventory is an example of such an activity. The backflush system is very similar to the periodic system of inventory, and the authors feel that it does not provide management with enough accounting information on which to base its decisions. A perpetual system based on standard costs seems to provide more information to management than a periodic system when significant raw material or WIP inventories are still present.

The discussion of the methods above suggests that there are no clear cut answers as to how a cost accounting system should be structured in a JIT environment. Both of the methods described seem to make sense under certain circumstances. Under a true JIT system, the backflush costing approach may be all that management needs since any WIP or raw materials inventory will be insignificant. However, as explained above, some companies using JIT still maintain raw materials and WIP inventories, and under the backflush system this inventory is not valued continually. Therefore, a perpetual type inventory system may be more appropriate.

In addition to the many accounting changes, and the choice of accounting methods discussed thus far, a company may also need to develop a new costing method for its products. The study by [21, 28] shows that surveys conducted by Price Waterhouse have revealed that a majority of companies regard their existing costing system as inadequate even under their current approach to manufacturing. Therefore, it is not surprising that the introduction of JIT will require a new approach to costing systems, As [31, 35] stated

“The key to designing the improved costing systems that are required is to understand the underlying business, and the way it conducts its operations, and then to build the costing system around those structures.”

Additional findings in their study shows various tools are available that may lead to improved costing systems. These tools are considered compatible with the implementation of JIT manufacturing. They include the following: activity-based-costing, target costing, improved standard costs, life cycle costs, and improved investment justification techniques. Activity-based-costing is an approach to overhead costing which attempts to identify the factors which influence the cost. Costs are apportioned to products based on cost drivers which may include the number of set-ups in a manufacturing process, the number of material movements, or the number of different product variations. Target costing attempts to determine the target cost of the product in the long-run by determining what price consumers will be willing to pay for a product and then working backwards to achieve a target cost based on that selling price. Standard costs will still play a key role in measuring monthly performance. JIT attempts to eliminate wasted costs such as the cost of scrap, and the cost of moving and storing materials and inventory. Therefore, these costs must be measured in order for them to be reduced, Improved standard costs can be related to target costing, Standard costs will be the costs expected to be achieved for a particular period, usually one year, while the target costs is the cost to be achieved over a longer period of time, Over time, the goal is for the standard cost to equate to the target cost. Life cycle costs are relevant when products are subject to rapid obsolescence, and where the cost of designing the product is a major component of long-term profitability. Traditionally, costing systems are focused on the manufacturing process, life cycle costing will entail involvement at the designing stage of the product. [11, 19] stated

"Capital investment justification techniques must be improved to take account of the impact of improvements in areas such as inventory holding costs and quality. The goal is to maximize output of the organization as a whole and not the individual stations."

A related technique involves the concept of maximum potential throughput (MPT). The MPT is the theoretical capacity that could be achieved in

the absence of any waste. Capital investment should strive to increase actual output to the MPT level. Of course, market demand constraints must also be taken into account. There are many cost accounting implications associated with the implementation of JIT processes. In terms of inventory costing for financial reporting purposes, inventory should be immaterial and constant from year to year under a true JIT system. Therefore, cost of goods sold will equal cost of goods manufactured. The unit cost concept is greatly affected by JIT. The process improves quality, productivity, and reduces product costs.

Accountants need to be aware of all of the accounting changes that may be necessary because of JIT. Many of the cost accounting methods previously used may need to be modified. Since there are no established standards, accountants can develop accounting systems that directly satisfy management's needs. Attaining all of the JIT goals takes time and accounting systems should be modified as different levels of JIT applications are implemented. Accountants should keep in mind what JIT attempts to accomplish, and they should develop accounting standards that can measure those accomplishments. As more companies become aware of JIT methods, some uniformity in accounting methods and techniques will be established.

The implementation of JIT can provide many advantages to a company. The usage of JIT techniques can improve a company's problem solving capabilities by exposing problems in the production process as they occur. Problems do not remain hidden in excess materials as any problems encountered are immediately resolved. JIT reduces lead times and increases equipment utilization because of smaller lot sizes and delivery order sizes. Product quality is increased because quality is centered on the individual workers, and the workers are considered part of the team. Input from workers is encouraged. Adoption of JIT usually reduces paper work, and requires only simple planning systems. A reduction in inventory is always achieved as the JIT philosophy aims to eliminate nonvalue-added time or wasted time.

There are also some disadvantages associated with the implementation of JIT. It may be difficult for JIT to be effective in certain types of

environments. JIT requires an atmosphere of close cooperation and mutual trust between the workforce and management. It is usually not as effective when labor is unionized. The use of JIT production or purchasing requires a large number of production setups and frequent shipments of purchased items from suppliers. Therefore, suppliers become very important and crucial to the company's operations. The process is not well-suited for irregularly used parts or specially ordered products because it does not respond quickly to changes in schedules when there is little excess inventory available.

In conclusion, JIT is best suited for companies with uniform production flows, but as shown in the different examples discussed, JIT may be used virtually by all types of businesses. Although this paper focused primarily on manufacturing applications of JIT, the JIT philosophy can be applied to many types of organization. JIT techniques may be used in conjunction with other types of manufacturing systems. [1, 16] implies that even MRP systems may be modified and used in conjunction with JIT applications. Many companies have been successful in implementing JIT techniques, and they continue to try to improve their systems. Changes in cost accounting information provided under JIT environments have been diverse. Companies are making changes to their accounting systems as JIT implementation takes place. Most companies, under JIT, have been able to eliminate some of the detailed accounting information previously maintained. Presently, there is no one accounting method best suited for a company using JIT. The cost accounting system needs to be evaluated and modified, as necessary, to best fit the JIT requirements. The purpose of any cost accounting system is to provide management with useful information that will facilitate the decision making process. Under JIT, the cost accounting system should strive to achieve this same purpose.

The JIT methods can produce many advantages, and companies that have implemented JIT procedures have benefited from many of these advantages. The disadvantages discussed can be overcome through careful planning at the early stages of implementation and through continual monitoring of the process as the system grows. Applications of JIT will continue to expand in the

future as companies realize the many financial gains that JIT techniques can generate. Companies should definitely consider looking into JIT methods.

Research Gap

This study bridged a research gap by introducing a framework for re-design of manufacturing systems into practical optimum Just-In-Time systems by integration of computer simulation and analysis of variance. The conventional JIT approach is mostly applicable to static production systems and the dynamic production systems require a more practical integrated JIT approach. However, the re-design of existing dynamic systems into just-in-time systems must follow a practical path, which can be a cumbersome task. This means, a unique practical optimum just-in-time system that considers system's limitations and its dynamic behavior must be designed. To achieve the objective of this study, first, the actual system must be totally modeled and simulated. Second, the integrated simulation model is tested and validated by analysis of variance. Third, the optimum (most fitted) JIT design is developed and tested by modeling actual system's limitations and its dynamic behavior. The framework is applied and tested for a just-in-time production line.

This work unlike other previous studies develops an enhanced discrete event simulation JIT Manufacturing System Model. The system consists of components, people and machines that make useful products. The system is managed across boundaries and interfaces. The boundaries define the scope of the system or subsystem, while the interfaces control the flows through transactions.

There are three flows in the JIT Manufacturing System Model: the flow of materials, the flow of information, and the flow of cost. These flows establish the value streams. Components of the value stream can be value-add or waste, depending on the operating conditions. For example, excess material flows become a stream of inventories, while excess information leads to confusion in process execution. By managing the flows, we can control the streams. An effective control of these streams is required for lean production.

As mentioned earlier, the interfaces control the flow. For example a conveyor regulates the flow of materials and a visual control regulates the flow of information between two stations. The interfaces arise from disconnected points in the system, e.g., the physical distances between two machines, the communication barriers between two people, or the control panels between a machine and an operator. It is often a good location for cost transactions. As the number of components and interfaces grows, the machines become factories and the people become organizations.

In the enhanced JIT Manufacturing System Model, the parts represent the materials, while the kanban represent the information mechanism. In this way, we can analyze the efficiency of these flows. Associated with each device that handles the parts or kanban, a cost is applied to the operation of the device. Therefore a buildup of parts and kanban implies an increasing cost.

In summary, the studies in the literature have the following two limitations:

- The manufacturing systems for control have relatively simple structures. In fact, manufacturing systems are much more complicated in real factories.
- The control structures used are classic methods.

One of the reasons for these limitations is that there are no efficient methods for evaluating complex manufacturing systems with single-card pull system. Therefore, an efficient evaluation method such as optimal JIT system is desired such that the behavior of single-card pull system control can be explored to help design and control complex manufacturing systems. It would equally help examine the impact of manufacturing system alternatives within the context of today's increasingly time-based competitive environment.

The design of supply chain manufacturing systems has received immense attention by researchers and practitioners in many aspects. In this dissertation, there are four aspects considered are: Just-In-Time delivery operation system, time varying demand, flexible production capacity and integrated inventory system including raw

materials, Work in Progress (WIP), and finished products.

For an instance, in the JIT production system, the constant demand optimization model discussed by many authors [6, 13, 18, 33] would be inappropriate when the supply chain system faces time-varying demand over the planning horizon. If the supply chain system is optimized for the average demand then the system may experience severe shortage during the high season or may have to keep excessive stock during the low season. Severe shortage will result in not only loss of sales but also losing the willingness of customers in the future. In addition to incurring high holding cost, overstocked products in one season can be obsolete in the succeeding season.

Hence, a more appropriate policy is desired to better adjust the ordering and producing to meet the demand and results in a more cost-efficient supply chain and production system. The Blackburn & Millen and Nance models are limited to level demand and infinite planning horizon. Here, they only consider one type of shipment mechanism, which is fixed-interval and fixed shipment size. During the model development, some of the researchers [5, 9, 27] considered the issues of raw material, WIP and finished product inventories separately, it would be logical if all these issues are analyzed together.

For time-varying demand model, an exact solution procedure proposed by [10, 24] considered two-stage and multi-stage systems but they did not consider the manufacturing circumstance with flexible production capacity and the production rate of a manufacturing system is assumed to be predetermined and inflexible. Previous researchers ignored this type of models due to complexity of the problem. However, machine production rates can be easily changed and production cost depends on the production rate [1, 13, 34]. In this research, a model is developed with flexible production capacities as decision variables, which is a more general class of supply chain manufacturing system.

Most of past works in modeling and optimization of supply chain manufacturing system have so far partially considered the aspects of JIT delivery, time varying demand, integrated

inventory including raw materials, WIP and finished products and flexible production capacity separately. Combining these aspects to capture a more realistic situation in the modeling has received little attention. This research attempts to bridge this gap. It develops optimal and efficient operational methodology for the integrated inventory system including raw materials, WIP and finished products of a multi-stage production system with JIT deliveries that incorporates time varying demand under flexible production capacity. This research presents robust analytical results to solve the operational problems for such production system optimally.

This study integrates theory and methodologies from industrial engineering and operations management within a single research model and directly compares the performance of Just in Time Manufacturing System (JIT) in a controlled environment.

This study considers the interaction effects of the various Manufacturing System (MAS) alternatives with factors from operations management. The existing research in both managerial accounting and in production operations management often ignores the interrelationships among important factors. For example, most managerial accounting researchers are in agreement that activity-based costing provides more accurate product cost information than Just in Time Manufacturing System (JIT), and most managerial accounting research makes the assumption that more accurate product costs will improve the quality of product mix decision thereby improving firm performance [11, 22]. However, this assumption is made without examining important factors such as product complexity, scope of product mix, and manufacturing overhead levels, which in the real world application are as important as managerial accounting alternatives on product costing and product mix decisions.

The study goes a long way towards bridging this gap that has long existed between managerial accounting and operations management and between academic research and practice. A number of surveys have indicated that potentially up to 90% of all manufacturing companies are considering changes to their internal managerial

accounting systems, yet fewer than 20% have actually done so. One possible reason is the lack of knowledge about the various managerial accounting alternatives and their potential impact within various manufacturing environmental settings [14, 18]. The research “Optimal Common Frequency Routing (CFR) for a JIT System with Time-Varying Demand and Flexible Production Capacities” through evaluating Time Based Costing alternative with environmental factors that were previously studied separately within a controlled simulation environment, results should create common ground for communication between management accountants and operations managers. It equally goes beyond the more conventional deterministic managerial accounting research with the incorporation of demand and supply stochasticity within the simulation model.

Conclusion

Just-in-time manufacturing is a philosophy that has been successfully implemented in many manufacturing organizations. It is an optimal system that reduces inventory whilst being increasingly responsive to customer needs; this is not to say that it is not without its pitfalls. However, these disadvantages can be overcome with a little forethought and a lot of commitment at all levels of the organization.

JIT is likely to be one of the most suitable management concepts for today’s business because it meets the paradigms of new businesses such as rapid changes in demand and more customised products. This system is also based on aspects of continuous improvement such as continually reducing costs, defect, inventory and lead time. Since the system has never-ending objectives, it is suitable for companies that want to survive in tomorrow’s business world.

The JIT system does not just involve lowering inventory reduction or using Kanbans, but the most necessary elements of implementing a JIT system are empowering people and developing a humanised production system. These elements can be achieved only if a proper environment exists within the JIT company such as effective employee involvement and management commitment. Therefore, the role of management is then crucial for cultivating the environment.

The simulation of a JIT system can provide better insight into the effects of factors contributing to its successful implementation. Some factors such as the number of Kanbans, trigger points, the scheduling rules and location of the buffers that are difficult to evaluate in practice can be evaluated using the simulation. However, due to the capability of the software that was dedicated to the conventional push system, some figures generated from the simulation may need some interpretation before being applied in actual situations. Another problem in using simulations is the complexity of the model and the more accurate the system, the more complex the model. Unfortunately, the more complex model is usually difficult to interpret and it requires more time to develop and verify the model.

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