DESIGN AND IMPLEMENTATION OF MRP-JIT HYBRID SYSTEM UNDER DEMAND UNCERTAINTY

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ABSTRACT

This research presents of hybrid design of MRP and JIT system to improve the collaboration between a company with its supplier under demand uncertainty. A case of pigment inventory in a plastic injection manufacturing company is taken to understand the important aspects in implementing hybrid MRP-JIT system, where the aspects are reviewed from both practical and academic perspectives. The performance evaluated in this case study are related to inventory and production performance. The inventory performance is measured through the level of stockout, overstock, and non-moving stock. Meanwhile, the production performance is represented by the expected downtime. The process of analysis and designing the conceptual design of MRP-JIT system are presented in this research. The analysis is conducted to ensure that the characteristics of the case study match with the concept of MRP and JIT, so a literature study is required in this phase. Then, the MRP-JIT hybrid design is proposed to incorporate advantages of both MRP and JIT. MRP is adopted to improve the inventory process in terms of planning, while JIT is used to accelerate the inventory process in terms of operational implementation in the field directly. The contribution of this research is to provide a practical approach to adjust the needs of the manufacturing industry with cost efficiency.

Keywords: Inventory Management, Material Requirements Planning, Just-in-time, Replenishment Strategy.

1. INTRODUCTION

Material requirement planning (MRP) and Just-in-Time (JIT) are two different approaches in planning and controlling materials. MRP focuses on planning based on sales forecast, while JIT concerns on production taken from actual customer orders. Even though these methods have different forms and procedures, both have a similar goal, which are low total cost, high quality product, and high customer satisfaction. Thus, implementing MRP-JIT hybrid system can provide some advantages in manufacturing industries. This research uses a case study of plastic injection manufacturer in Indonesia to explore how MRP and JIT can be employed in a hybrid design. The case study in this work is a non-repetitive make-to-order (MTO) company. The main performance measure of this company is the percentage of orders that are completed on time to customers. This industry is highly dependent on seasonal, gender, age, and size, because the manufacturer provides supplies for a high-fashion-brand company. In addition, this industry's performance relies on inventory to ensure the customer satisfaction as well as high productivity. The customer satisfaction depends on the product quality and on-time delivery.

A challenge found in this case is that it is difficult to minimize the non-moving stock in the

manufacturer. It causes the inventory increases continuously if not solved. For example, the total non-moving stock of pigments in the last 6 years amounted to 7,913.38 kilograms with total asset inventory of USD 165,079.92. This number potentially increase continuously as long as the integration among departments are not well maintained into an integrated system. Also the demand uncertainty could amplify this problem moreover, if a further problem is not achieving production output, this can be detrimental to the company in terms of costs and affect the reduced service level due to late delivery. The most substantial downtime in the last 4 month caused by a pigment lateness with a total time of 28,494 minutes are repeated up to as much as 1,425 times, means average downtime 4,6 hours per machine with total 102 machine. Therefore, this research is very important from practical perspective for companies that have a stochastic inventory model with unpredictable demand patterns.

The inventory control method that is used in this research is a hybrid system between the Material Requirements Planning (MRP) method and the Just-In-Time (JIT) method. With the implementation of the non-repetitive make-to-order (MTO) production system. Based on the idea that MRP is able to respond better to uncertain demand and can change the order quantity by determining lot-sizing. According to Zhao & Lam (1997), a modified lot size rule is shown to reduce total costs and instability as well as improve MRP system performance. However, not all business lines are suitable to use the MRP system, and this system is not good enough in terms of field implementation. Meanwhile, JIT is able to minimize the inventory of goods in process because it reduces space and costs, thereby saving storage space and related costs. Kanban is one of the tools from JIT, both used as a signal that contains instructions for operation and material flow information. This research is also considered important from academic perspective because it can serve as a reference for similar research, in particular the implementation of a hybrid approach MRP-JIT in a manufacturing industry that is implementing production systems make-to-order (MTO), which is more common hybrid system discussed in repetitive manufacturing industry with make-to-stock (MTS) and assemble-to-order (ATO) systems.

The paper is structured as follows: In section 2 review related work research and gap. In section 3 concern on methodology, followed by outlines our replenishment system design in section 4. In section 5 we present interpretation of result. Section 6 concludes the paper with a discussion of the primary findings and their implications for future research.

2. RELATED WORKS

An important component in the integration between the MRP-JIT is to design a system that makes it easier to determine inventory. MRP can improve the inventory process in terms of planning and JIT accelerates the inventory process in terms of operational implementation in the field. It is advantageous to integrate JIT into the discipline of MRP to close the loop between the shop-floor with the medium- and long-term planning processes (Pun, Chin, & Wong, 1998). According to Flapper et al. (1991) either of these alternatives allows JIT to operate within the MRP. Because JIT operates by reducing inventory levels and lot sizes to expose problems, the following values updated in the MRP database lead time, lot sizes, and safety stock. Several reviews from previous research that discuss similar matters, namely the inventory control system with implementation and conceptual review literature. This research is expected to be able to determine the development of the research topic that is raise. The several previous research journals can be seen in Table 1.

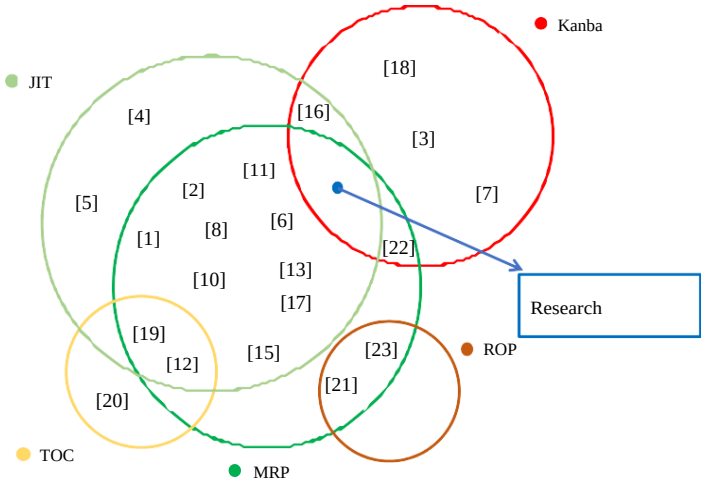
Tabel 1. Previous Research Journal

Authors	Journal Title	Research Result
Pun, Chin, & Wong (1998)	Implementing JIT/MRP in a PCB Manufacturer	• The inventory level is reduced by 20% in WIP with the Kanban systems • Supplier lead time is reduced by 30% as more local sources areappointed.
Foo & Kinney (1990)	Integrated pull manufacturing-the integration of MRP and JIT systems	• The total inventory at the plant was reduced by 90%and Inventory turnover ratio increases.
Rahman, Sharif & Esa (2013)	Lean Manufacturing Case Study with Kanban System Implementation	• Operating costs, waste, residual and losses are minimized, excess production stock is controlled with flexible work stations.
Cua, McKone, & Schroeder (2001)	Relationships between implementation of TQM, JIT, and TPM and manufacturing performance	• The adoption of manufacturing practices intended to reduce variability and increase productivity will minimize costs and increase shipping.
Fullerton & McWatters (2001)	The production performance benefits from JIT implementation	• The results of this study indicate that the implementation of JIT improves competitive performance by decreasing inventory levels and reducing quality costs and processing time.
Chen & Shang (2008)	Manufacturing planning and control technologyversus operational performance: an empiricalstudy of MRP and JIT in China	• MRP performs well in the planning and control areas and operational performance. • The JIT embedded MRP system is a much more efficient system and combining the MRP and JIT philosophies helps to create synergy and achieve better performance than implementing anyone individually.
Hao & Shen (2008)	Implementing a hybrid simulation model for a Kanban-based material handling system	• The JIT-Kanban principle is applied to the production process and material handling. The main objectives of this research are to develop a prototype software system to simulate a flexible production line pull, to demonstrate a dynamic material handling environment, to optimize material transport flow, and to make accurate statistics and predictions.
Matsuura, Kurosu, & Lehtimäki (1995)	Concepts, practices and expectations of MRP, JIT and OPT in Finland and Japan	• In JapancompanyMRP is used to make detailed capacity planning and material planning, control of production activities is carried out by JIT.x • In Finland, the concepts post-MRP and post-JIT are not used, post-MRP will be a simpler, lighter and more flexible system.
Spencer (1995)	Production planning In a MRP/JIT repetitivemanufacturing environment	• The JIT method is best used to supplement rather than replace the MRP method in production planning and control in a repetitive manufacturing environment.The integration of JIT into the MRP (CIM) environment appeared to be working for the factory, and management showed little desire to devote computers to production planning.
Flapper, Miltenburg, & Wijngaard (1991)	Embedding JIT into MRP	• JIT reduces setup time, labor time, machine time, material costs and tooling costs then lowers production costs and is reported by MRP.

Authors	Journal Title	Research Result
Miltenburg (2001)	Computational complexity of algorithms forMRP and JIT production planning problems in enterprise resource planning systems	• Compared to MRP, JIT has almost no difficulties with material planning. Companies using JIT will simplify it first then plan
Miltenburg (1997)	Comparing JIT, MRP andTOC, and embedding TOC into MRP	• JIT provides high output with the lowest inventory and the fastest cycle times and requires no expedition, while TOC provides the highest output and targets improvement activities in areas that affect output the most.
Ming-wei & Shi-lian (1992)	A hybrid system of manufacturing resourceplanning and just-in-time manufacturing	• In order to properly consider lot size and lead time, the MRP methodology is more suitable than the pull-system. • The decision whether a part will be processed in MRP or JIT will be taken after the explosion bill of materials. In this kind of hybrid system, the whole product is mostly reproduced repeatedly.
Benton & Shin (1998)	Manufacturing planning and control: The evolution of MRP and JIT integration	• The JIT production system requires reduced lot sizes, setup times and unique facility layouts.
Ho & Chang (2001)	An Integrated MRP and JIT Framework	• An integrated system that combines the scheduling and capacity planning aspects, provides a detailed shop-floor schedule.
Kumar & Panneerselvam (2007)	Literature review of JIT-KANBAN system	• Minimizes processing timeand maximizes path efficiency. • Improvements in demand forecasts and decreased lead-time
Shah (2018)	New Planning System and Hybrid MRP-JIT Production Control	• The MRP system is used for material planning and for generating purchase orders.The manufacturing process is set up as cells operated by the JIT system, using cards or other
Huang & Kusiak (1996)	Overview of Kanban systems	• The concept of the Kanban system applies to a manufacturing repetative environmentand take into account factors such as lot size, setup time, yield loss, labor flexibility, product customization rate, and product structure. • The function of inventory in the Kanban system is to stabilize demand rather than balance regulatory costs and operate effectively, delivery times and the quality of upstream suppliers.
Gupta & Snyder	Comparing TOC with MRP and JIT: a literature review	• JIT demonstrates that JIT systems are more suitable for repetitive manufacturing environments and are as good as TOC-based systems.
Goyal & Satir (1989)	Joint replenishment inventory control:Deterministic and stochastic models	• The deterministic co-replenishment model approaches the objective of minimizing inventory-related costs by calculating (near) the optimal order cycle time values and positive integers for the order cycle frequency for each item.
Axsäter & Rosling (1994)	Multi-level production-inventory control:Material requirements planning or reorderpoint policies?	• Kanban system may still be advantageous compared to MRP, eg. due to lower administrative costs. • The lot sizes for different items must have integer ratios. In addition it is required that none of the items piled up a lot in the beginning.

Authors	Journal Title	Research Result
Rees, Huang, & Taylor (1989)	A comparative analysis of an MRP lot-for-lot system anda Kanban system for a multistage production operation	• The advantages of the JlT system include shortened cycle times and reduced installation time,costsandMRP will increase as the lot size decreases, thus matching the assumed profit of JlT-MRP handling lumpy demand better than Kanban.
Jacobs & Whybark (1991)	A Comparison of Reorder Pointand Material Requirements PlanningInventory Control Logic	• ROP logic Integrate into the MRP system should be done with caution. Whenever the uncertainty is caused by random yield factors, unstable master production schedules, or variations in requirements. • The JIT control system is built on a levelized (constant) and frozen (low uncertainty) schedule. Importance of level, frozen schedule for the success of the JIT program.

In Figure 1. there are gaps in the MRP, JIT and Kanban systems at that point the author tries to conduct research with direct implementation in the manufacturing industry as a replenishment strategy for the inventory process. Many previous studies have applied this method, but it is recognized by experts that this method is good for use in a manufacturing repetitive industrial environment which is usually applied to industries with a make-to-stock (MTS) system.



[1] Pun, Chin, & Wong (1998)
[2] Foo & Kinney (1990)
[3] Rahman, Sharif & Esa (2013)
[4] Cua, McKone, & Schroeder (2001)
[5] Fullerton & McWatters (2001)
[6] Chen & Shang (2008)
[7] Hao & Shen (2008)
[8] Matsuura, Kurosu, & Lehtimäki (1995)
[9] Spencer (1995)
[10] Flapper, Miltenburg, & Wijngaard (1991)
[11] Miltenburg (2001)
[12] Miltenburg (1997)
[13] Ming-wei & Shi-lian (1992)
[14] Benton & Shin (1998)
[15] Ho & Chang (2001)
[16] Kumar & Panneerselvam (2007)
[17] Shah (2018)
[18] Huang & Kusiak (1996)
[19] Gupta & Snyder
[20] Goyal & Satir (1989)
[21] Axsäter & Rosling (1994)
[22] Rees, Huang, & Taylor (1989)
[23] Jacobs & Whybark (1991)

Figure 1. Mapping of Research Positions and Gaps

3. METHODOLOGY

Inventory control method that used in this research is a hybrid system of MRP-JIT. There are several works that need to be done beforehand to streamline the MRP-JIT process with this system Kanban, namely:

a. Change Article / validated Document to be integrated (Online)

Article Document is a data bill of material, in which there is information about the product such as the material used, pigment composition, and product weight. Therefore, the calculation and planning of pigment supply requirements is done

manually and is quite time consuming due to the large number of different items.

b. Integrating the Working Order (WO) system with the MRP-JIT system

WO serves as proof of material demand from production to related department. WO is integrated with the master production scheduling (MPS) system. By integrating WO in the Kanban system, it can facilitate the flow of the replenishment process in pigment supplies.

Some of the company's data is needed in this study such as, article/validated document, non-moving stock of pigment, overall equipment effectiveness (OEE), the purchase price list and MOQ, customer orders, inventory, forecasting, and bill of materials on ERP. The data will be processed in the system into material requirement planning (MRP), and generate output in the form of Kanban parameter data.

4. REPLENISHMENT SYSTEM DESIGN

4.1 The Old Replenishment System.

As mentioned in section 1, inventory performance is measured through the level of stockout, overstock, and non-moving stock. This is caused by inaccuracy in the planning of pigment inventory. Previously, pigment supply needs planning was done manually, by calculating the number of outsole orders from customers with the article document as a reference, Therefore, this research is very important for companies that have a stochastic inventory model with uncertain demand patterns.

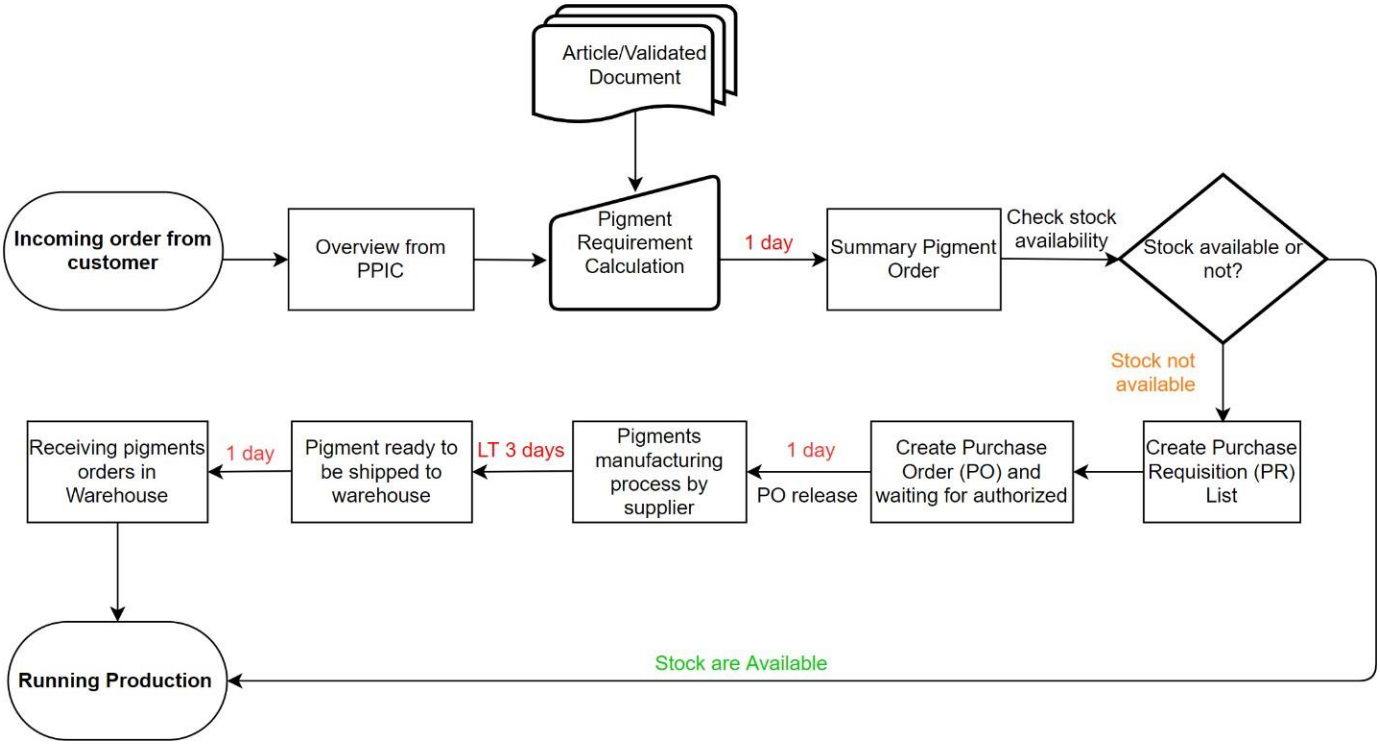


Figure 2. Current flow process supply

From the flow process above, we can see that the process is quite long, starting from the initial process of ordering pigment / masterbatch to arrival at the warehouse which takes approximately up to 6 working days, and have to potential of pigment stockout. Safety stock is

needed to meet production requirement. Returning to the problem at the beginning, namely the accuracy in calculations and the unavailability of forecasts in the current condition is one of the causes of the accumulation or non-moving stock of pigments and masterbatches.

4.1 The MRP-JIT Hybrid Design

This system design performs replenishment control on the pigment inventory associated with the supplier. Therefore, in the process flow that design in the system, involving on plan that is carry out using MRP, operational / execution which used in the JIT concept on the process, then the supplier have to follow the process in the replenishment system. An important component in the integration between MRP-JIT is to design a system to make it easier on determine inventory as follows:

a. Calculating Pigment Requirements with MRP system

The data needed in calculating pigment requirements is Article Document Online, data will proceed with Customer Order. From these two data, MRP is used in purchasing pigments according to orders from the customer to minimize deficiency of purchasing pigments. Also, determine the pigment purchase plan for next potential order which is called Buyplan data.

The Kanban parameter used in determining the design of the Kanban card in this study is called barcode labels, then determining the lot-size for each pigment in this study is called containers, then determining the number of containers (Kanban Cards) circulating in the field, and finally design flow process Kanban system.

b. Determine the Lot-Size for batch requirements on Kanban System

In implementing the MRP-JIT, lot-size is very necessary to determine the number of batches in the Kanban system and the frequency of shipments from suppliers. From the data obtained from the forecast, the safety stock (SS) and Re-Order Point (ROP) amount will be determined for each pigments, using the formula as below.

SS (*Safety Stock*) = $Z \times \sigma_L$

Information:

L : Lead time(LT)

Z : Service level(SL)

σ_{dl} : Standard deviation of demand during lead time

And;

ROP = *lead time demand* + *safety stock*

ROP = $\mu_L + (Z \times \sigma_L)$

information:

μ : Average demand

L : Lead time(LT)

Z : Service level(SL)

σ : Standard deviation of demand

There are 3 sections in the Flow Data Process Replenishment System Design with MRP-JIT, In section 1, Data used in process into MRP as an output which used in Kanban parameters. then in the Section 2, JIT accelerates the inventory process in terms of operational implementation in the field. In this section data is executed in the replenishment pigment / masterbatch process. The process running digitally to reduce manual calculations, paperless, reduce the purchase process cycle time and human errors. In the last section is the process that must be followed by the supplier, the Kanban cycle process run continuously.

The flow of replenishment process with MRP-JIT design can be seen in Figure 3.

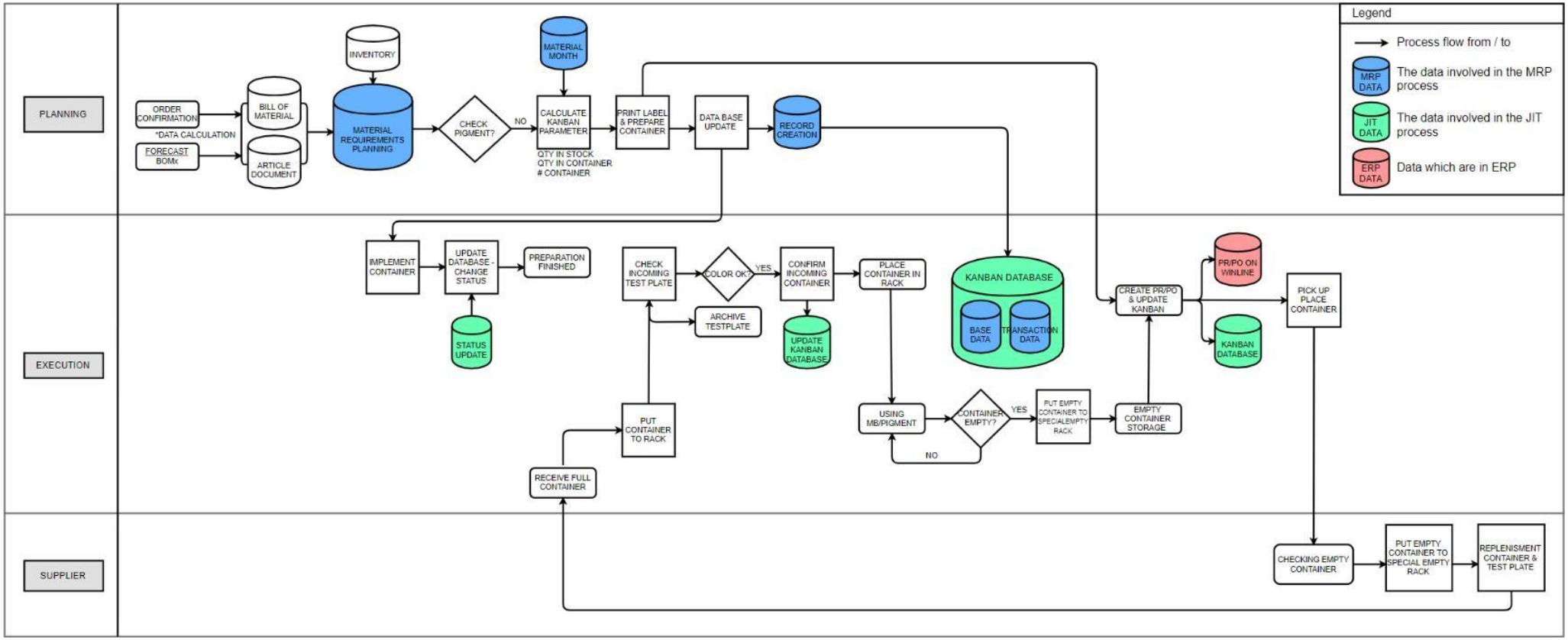


Figure 3. Flow Process Replenishment System Design with MRP-JIT concept

Several processes are replace into an integrated system, the required data flows quickly to get a decision. For pigment planning, now it has been integrated with Article / validated document in the form of MRP. To generate calculations until the PO release take same day as with arrival order from customer. With this flow process, suppliers can prepare buffer stock according to the forecast that has been shared. This resulted in a shorter lead time (LT). With this replenishment design, supply chain flow is more responsive and JIT's main target is achieved to deal with incoming orders. As can been seen in figure 3.

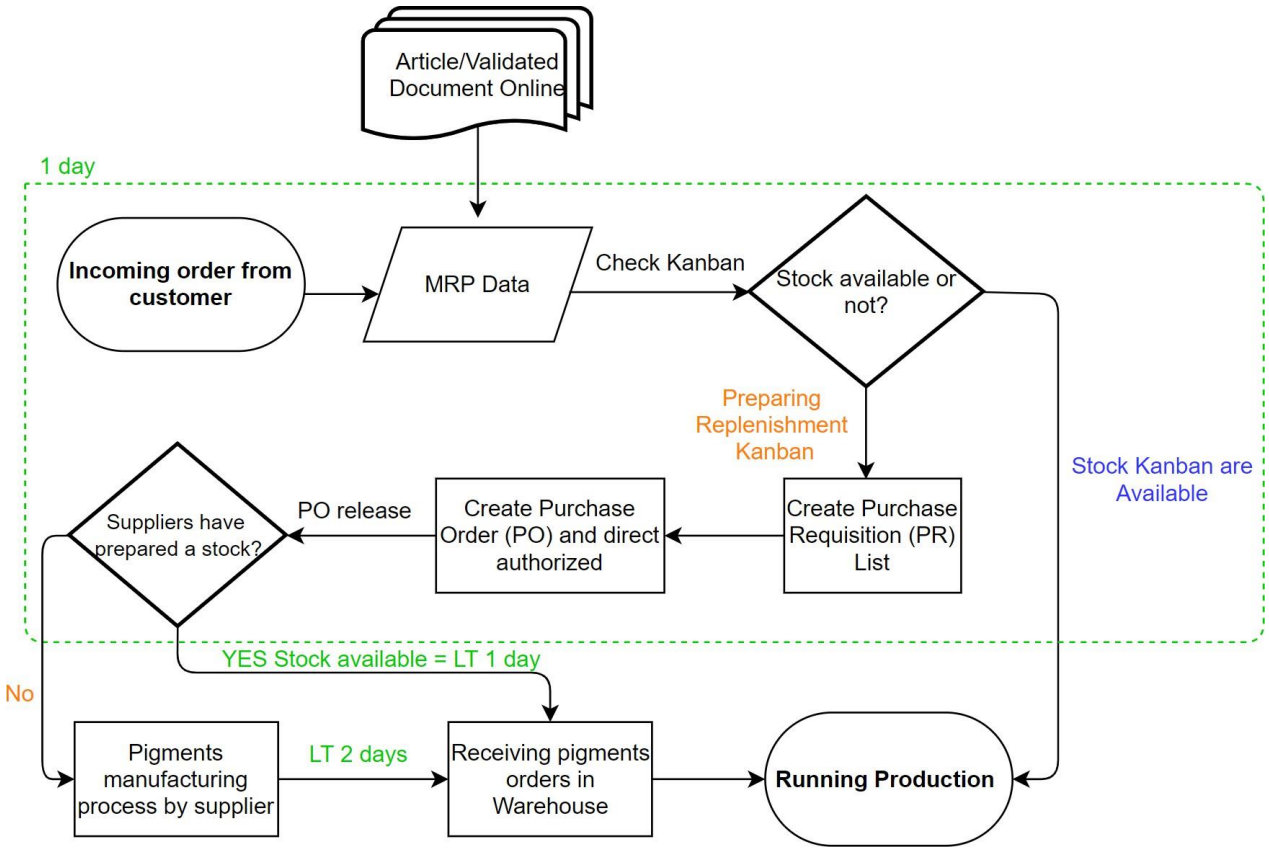


Figure 4. Kanban flow process supply and replenishment.

5. RESULTS

The data needed to analyze the results, namely by means of non-moving stock pigment, is data that contains historical stock pigments for which there are no transactions each year. From these data comparing with the latest data after this research was conducted. Overall Equipment Effectiveness (OEE) data, namely performance measurement data related to the availability of productivity and quality processes. seen from table 2, the overall Equipment Effectiveness (OEE) data for downtime due to shortage of pigment which initially occurred 1,425 times for a total of 28,494 minutes. After the implementation of this system, it decreased 54.55% for event times to 592 times with a total time of 12,950 minutes or a reduction of 58.46% from the previous condition. Inventory non-moving stock it's also decreases following by total asset inventory reducing around 70%. In terms of inventory, the average inventory quantity in the warehouse was reduced by 53.3% because the inventory level was limited by following quantity of numbers of Kanban container.

Tabel 2. Comparative Analysis

Data	Description	Unit	Before	After	%
Overall Equipment Effectiveness (OEE)	Accumulated pigment lateness	Minutes	28,494	12,950	54.55%
		Frequency	1,425	592	58.46%
Inventory non-moving stock	Total pigment inventory data that does not move or there are no usage transactions	Kg	258.21	77.04	70.16%
		USD	$ 8,420.46	$ 2,466.03	70.71%
Inventory Level	Average inventory quantity in warehouse	Kg	30.0	14.0	53.3%

6. CONCLUSION AND FUTURE WORK

From this research it can be concluded that the MRP system is good at planning pigment supply. in this study can reduce the loss that has implications for overstock / non-moving stock. Meanwhile, JIT with tools supplier Kanban is very appropriate when combined with MRP because it is good from the operational point of view of pigment supply. However, further research is still needed, especially in determining policies to make it easier for suppliers in terms of operations and delivery which become benchmarks for the replenishment operating system. The following research plan is to optimize the functioning of this system and turn it into digitization. The digitalization is expected to make it easier to implement the system accurately with real-time data, the resulting information can connect several departments, so that it is expected to facilitate decision making.

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