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Developing Production Planning and Control System by Applying Dispatching Rules: A Case Study at A Packaging Manufacturer

Fransiskus Xaverius Dimas Adrian Brahmantyo [1], Ivan Kurniawan[1*], and Triarti Saraswati[1]
[1] Department of Industrial Engineering, Faculty of Engineering and Information Technology, Swiss German University, Alam Sutra, Tangerang, 15143, Indonesia
E-mail: fransiskus.brahmantyo@student.sgu.ac.id[1], ivan.kurniawan@sgu.ac.id[1], triarti.saraswati@sgu.ac.id[1]

Abstract

Production planning and control (PPIC) is a critical element in manufacturing process. PPIC consists of a lot of activities which lead complexity within its system. Problems such as amount of safety stock, parts inventory, and production scheduling commonly occurs within manufacturing process. A need of efficient PPIC system become an important factor in smoothing the production process which affect company's profitability and sustainability. This research provides production planning and control system which developed based on implementation of pull system, optimal safety stock calculation, and dispatching rules for the sequencing of the production scheduling. A case study in a packaging manufacturer is provided for testing the proposed system. A comparison analysis is conducted and it consists of the safety stock calculation, parts inventory on hand, and the economic analysis. From the improvements, positive results are obtained. The accumulation of final parts inventory and average daily parts inventory are reduced up to 38%. Safety stock of sub-product reduced up to 82% and the safety stock of holding cost are reduced by 77%.

Keywords*: Production Planning and Control, Pull System, Dispatching Rules, Safety Stock, Inventory Management, Packaging Manufacturer*

1. Introduction

A company is always expected to deliver their product to their customers on time in order to maintain a high customer satisfaction. Figuring out the actual demand might be one of the hardest parts for a company to maintain a high revenue and at the same time low production cost (Leng et al., 2020). However, things are quite different for companies that provide product customization for their customers. Product customization occurs when a company provides customers with the ability to modify product specifications to meet their individual needs and preferences. This approach allows for tailored products that enhance customer satisfaction and can differentiate a company in the competitive market (Pallant et al., 2020; Wedowati et al., 2018).

It is challenging for companies to accurately forecast demand when offering product customization due to the varied preferences of individual customers. Each customized product order can differ significantly, making it difficult to predict the exact quantity needed (Ngniatedema et al., 2015; Shi et al., 2020). Consequently, companies that provide product customization must adopt a unique production strategy compared to those producing standardized, mass-produced ítems (Cheng, 2023). Implementing an effective production planning and scheduling system becomes crucial in this context to ensure that customer demands are met efficiently. This approach helps manage the complexities of customized production, ensuring timely delivery and maintaining high levels of customer satisfaction (Afolalu et al., 2021; Liu et al., 2022).

One key aspect of production planning and control is the application of dispatching rules. Dispatching rules are a set of guidelines that determine the priority in which customer orders are processed on the shop floor (Liu et al., 2022). Applying the right dispatching rules can significantly improve production efficiency, throughput, and on-time delivery (Chen et al., 2012; Chik et al., 2004).

In this paper, a case analysis explores the development and implementation of a production planning and control system by a packaging manufacturer using dispatching rules to optimize their operations. The objective of the Production Planning and Inventory Control (PPIC) system is to enhance efficiency in production planning and scheduling while maintaining

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[1*] Ivan Kurniawan

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optimal levels of safety stock. This case study adopts a demand-oriented or pull system strategy, which focuses on producing goods based on actual customer demand rather than forecasts. By aligning production closely with demand, the manufacturer aims to decrease safety stock and parts inventory, thereby reducing excess inventory costs and improving overall responsiveness to market fluctuations. Furthermore, this research constitutes to the six sigma method (DMAIC; Define, Measure, Analyze, Improve and Control) as it is suitable for this case in applying for improvements with the current situation and system in the packaging manufacturer. This system is tested in an Indonesian packaging manufacturer, established in 1996, that accommodates both mass production and product customization. The PPIC system is specifically designed to minimize safety stock levels, thereby reducing holding costs. Furthermore, it aims to lower parts inventory on hand, resulting in additional cost savings. The system incorporates daily tracking of parts inventory, facilitating more effective production planning. This integrated approach ensures streamlined operations, significant cost reductions, and improved responsiveness to customer demands.

The rest of this paper organized as follows. Section 2 discusses relevant literature review regarding agent-based simulation and human–machine collaboration. Section 3 details the research methodology, simulation model regarding the case study and proposed scenarios. Section 4 describes the result and analysis of steady-state simulation. Section 5 concludes the result of the research and also gives an insight into future research.

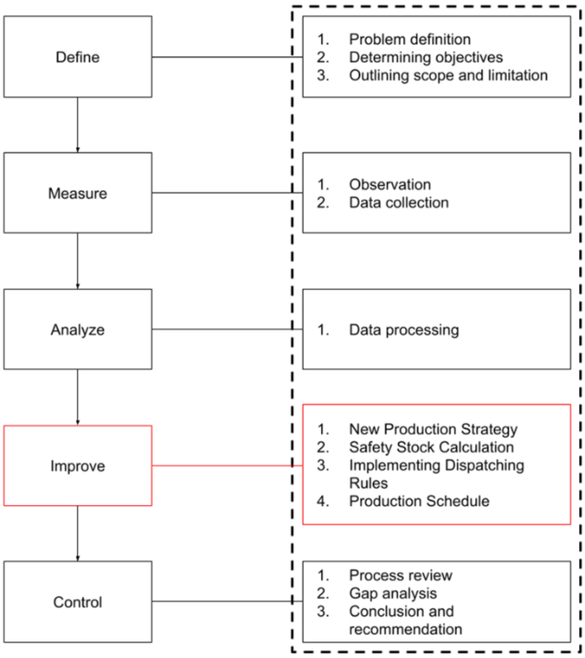

Figure 1: Research Methodology by Using DMAIC

2. Research Methods

2.1. State of the Art

The packaging manufacturing industry, operating on a global scale, encompasses a diverse array of segments, each exerting significant influence over market dynamics (Wyrwa & Barska, 2017).

Table 1: Literature Related to PPC & Inventory Optimization

Author	Title	Research Focus	Publication
(Kaban et al., 2012)	Comparison of Dispatching Rules in Job-Shop Scheduling Problem Using Simulation: A Case Study	The significance of dispatching rules in enhancing the factory's performance is discussed in this essay. A total of 44 dispatching rules, divided into hybrid and single rules, are evaluated in this study.	International Journal of Simulation Modelling
(Singh & Ahuja, 2012)	Just-in-Time Manufacturing Literature Review and Directions	This study intends to offer an overview of JIT implementation strategies used by industrial firms as well as a thorough assessment of the literature on just-in-time (JIT).	International Journal Business Continuity and Risk Management
(Becker et al., 2013)	Dynamic Safety-Stock Calculation	This study examines tried-and-true mathematical formulas for calculating safety stock. As a result, the stock and service level performance is evaluated, and the limitations of various approaches are shown	International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering
(Tsai et al., 2014)	A Comparative Study of Pull and Push Production Methods for Supply chain Resilience Pull and Push Production Methods for Supply Chain Resilience	The pull and push supply chain management systems are explored, as well as resilient supply chains. To evaluate both management techniques' durability, the study does an experiment.	International Journal of Operations and Logistics Management
(Peeters & van Ooijen, 2020)	Hybrid make-to-stock and make-to-order systems: a taxonomic review	The paper evaluates the literature that has already been written in the field of production system. The research classifies it using a new taxonomy, and identifies the many applications of hybrid MTS/MTO production control. The publication also offers a summary of the modeling approaches and procedures	International Journal of Production Research
(Seyedan et al., 2023)	Order-up-to-level inventory optimization model using time-series demand forecasting with ensemble deep learning	This study focuses on forecasting future demand within the online retail sector by utilizing ensemble deep learning-based methods and comparing their performance. Ensemble learning enhances prediction accuracy by combining the strengths of multiple models, in contrast to single-model approaches. By integrating the benefits of both deep learning and ensemble learning, ensemble deep learning models offer improved generalizability, making the final predictive model more robust and versatile.	Supply Chain Analytics

Table 2: Research Positioning Compared with Previous Researches

Reference	Methods			Case Objects		Supporting Tools	
	Pull Systems	Push Systems	Scheduling and Sequencing	Production	Inventory	Information System	Manual
(Kaban et al., 2012)			✓	✓		✓	
(Singh & Ahuja, 2012)	✓	✓		✓	✓		✓
(Becker et al., 2013)					✓	✓	
(Tsai et al., 2014)	✓	✓			✓	✓	
(Peeters & van Ooijen, 2020)	✓	✓		✓			✓
(Seyedan et al., 2023)					✓	✓	
Proposed Research (2024)	✓		✓	✓			✓

Manufacturers are leveraging this trend to tailor their offerings to individual consumer needs, thereby enhancing satisfaction and fostering brand loyalty. This pursuit of customization not only provides greater design flexibility but also ensures that products meet unique consumer desires (Wu et al., 2023). In tandem with customization, production planning and control (PPC) assumes a vital role in ensuring the seamless availability of materials and components essential for assembly. PPC, an integral part of the production system, is pivotal in optimizing operations, minimizing costs, and enhancing product quality to boost customer satisfaction.

By embracing lean manufacturing principles rooted in continuous improvement, manufacturers streamline processes and eliminate waste, achieving greater efficiency with fewer resources (Mrugalska & Wyrwicka, 2017). These lean methodologies, including push, pull, and push-pull systems, optimize workflow efficiency and inventory management, thereby enhancing productivity and cost-effectiveness (Javadian Kootanaee et al., 2013). Table 1 represents several previous research that associated with the research in this paper. Table 2 plotted this research position compared to the previous researches. In this research, pull system, scheduling and sequencing become the primary methods. However, the current PPC processes is still run in manual rather than using information system.

2.2. DMAIC Methodology

The main methodology that used in this research is DMAIC (Define, Measure, Analyze, Improve and Control) methodology. DMAIC is a robust performance improvement model that based on lean manufacturing principles was employed to enhance a company's processes and products to achieve strategic objectives (Trimarjoko et al., 2020). This methodology, divided into five distinct phases, provides a structured framework for identifying problems, analyzing data, implementing solutions, and ensuring sustainable improvements. The DMAIC methodology is employed to develop and implement a production planning and control system for a packaging manufacturer (Ahmed et al., 2020; Arafeh et al., 2018).

2.2.1. Define

During the first phase of the research, the problem statement is articulated, objectives are established, and the scope and limitations are outlined. The packaging manufacturer under study is currently facing challenges in minimizing safety stock and parts inventory. Notably, parts inventory is only recorded monthly rather than daily, and production planning heavily relies on the intuitive judgments of the Production Planning and Inventory Control (PPIC) team. Consequently, decisions regarding the quantity and timing of sub-product production, as well as overall production scheduling, are influenced by these subjective assessments.

The primary objective of this research is to enhance the company's Production Planning and Control (PPC) system. This includes reducing safety stock levels, lowering parts inventory, implementing daily tracking of parts inventory, and improving production scheduling. By achieving these goals, the research aims to optimize inventory management and production efficiency.

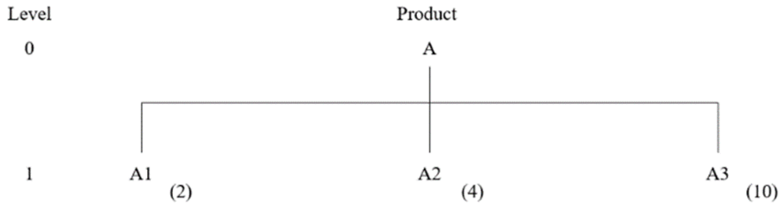

Figure 2: PBS of Product A

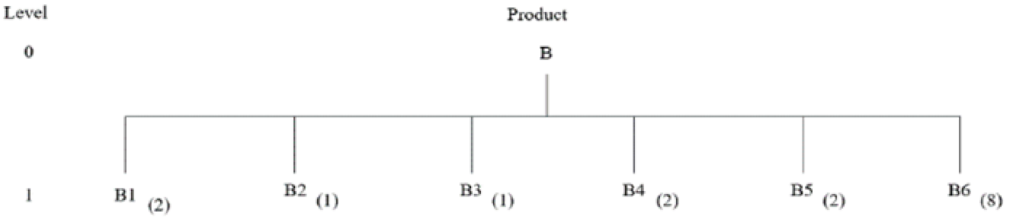

Figure 3: PBS of Product B

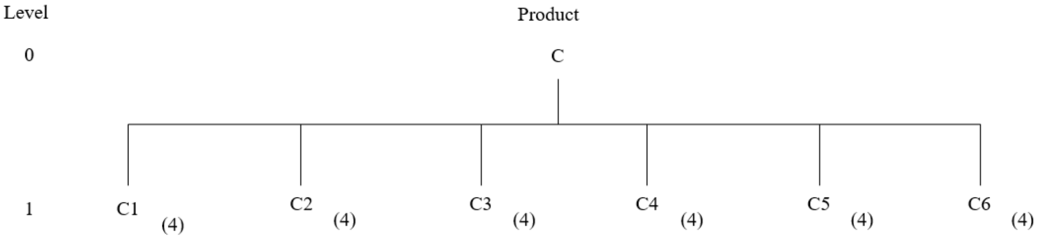

Figure 4: PBS of Product C

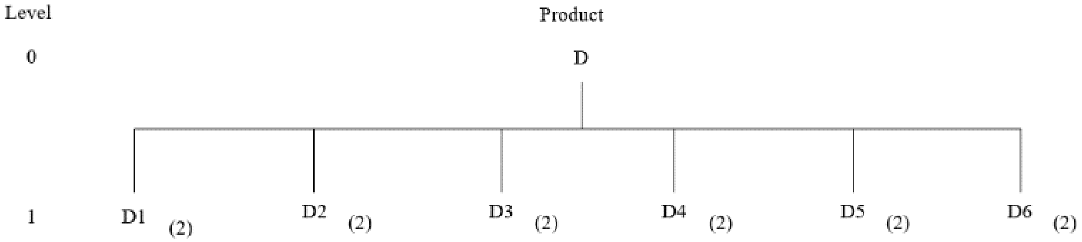

Figure 5: PBS of Product D

2.2.2. Measure

The second phase of this research is measure. In the measure phase, an observation of the production area was conducted to understand actual practices, collecting data on process performance, and analyzing this data to establish a baseline.

Relevant data for this research are collected from the packaging manufacturer. The packaging manufacturer produces four main products: edge protectors, foam packaging, consumables, and pallet combinations with each having various sub-products constructed from different parts. To help fulfill the customer demands, customers are required to submit a purchase order one week prior to their first delivery order. However, despite this preparation, the company is facing difficulties in determining the amount of safety stock on hand, inventory inefficiencies, and several production plans that are still based on intuitions

One of the most important data required in this research is product breakdown structure. The product that will be used for this research is the foam packaging product that contains four sub-products. The product breakdown structure of each sub-products will be made to help better understand the required quantity of parts to manufacture each sub-product. Each of the sub-product represented by Product Breakdown Structure (PBS) of product A (Figure 2), PBS of product B (Figure 3), PBS of product C (Figure 4), and PBS of product D (Figure 5).

The second data require is production floor layout which able to represent part process Flow. The part process flow shows the exact flow of the task to complete the production of each sub product. It is required to know the flow of the task as the production is a flow shop. Figure 6 represent the current floor layout of the case study and Figure 7 represent the current procedures of production mechanism in the company.

The third data required is production time. The production time is divided into two sections which are the production time and assembling and packing time. The production time shows all the task along with the time to produce all the parts of the sub products while the assembling and packing time shows the time for all assembling and packing to complete the sub product production.

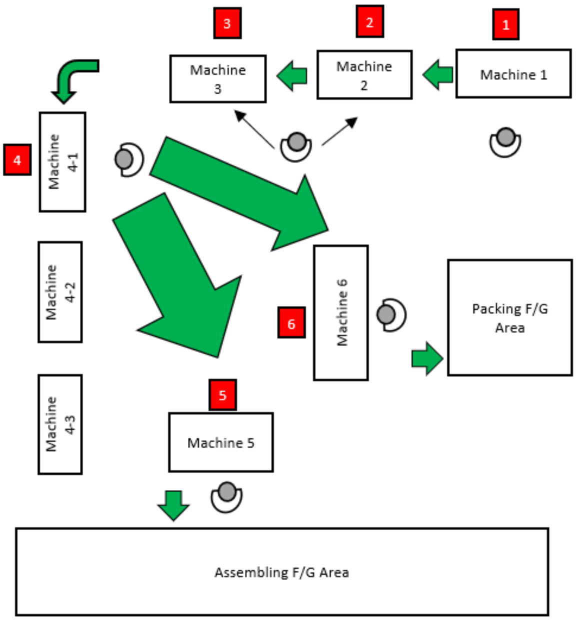

Figure 6: Case Study Process Flow Layout

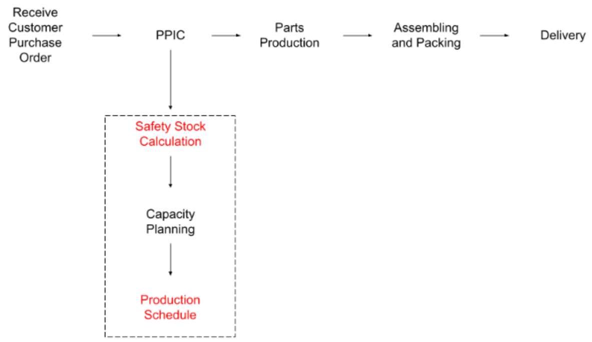

Figure 7: Procedures of Company's Production Mechanism

The last data required that need to be measure is customer purchase order. Table 2 represent a sample of company's purchase order for a month that based on the four product types (figure 2, figure 3, figure 4, and figure 5).

Table 3: Customer Purchase Order

Date	Customer Purchase Order (set)			
	A	B	C	D
1	30	20	35	3
2	20	20	15	47
3	20			50
4		20		50
5				
6	20			15
7	10			35
8	10			
9	40			
10	10			
11				
12				
13	28			
14	20	20		
15	13	20		
16	40	20		20
17				20
18				
19	10		25	
20		20		7
21				50
22	10		25	
23	20	20		
24				
25		20		
26				
27	20	60		
28	10		25	

2.2.3. Analyze

The analyze phase is for analyzing the company's current condition. The elements being discussed are the current safety stock, current production flow, current production planning and current parts production in the company.

Currently the company is using a policy which enforced the company to have a safety stock of each sub product that is twice as much as the largest demand during that month.

$$SS = 2\,x \max f[D] \tag{1}$$

SS = Safety Stock
D = Demand

Furthermore, in some cases, the safety stock calculations are not realized due to the production team's intuitions. The current production strategy utilized by the company is the make-to-stock production for every sub-product and is not based on the demand (Push system). Productions are triggered when the stock reaches below the safety stock level. Table 4 represent the current production planning for sub-product A, B, C, and D.

Table 4: Current Part's Production Order

Sub-Product A	Current Part's Production		
	1 Block of Styrofoam (set)	Qty Block Used (block)	Sets Produced (set)
A1	210	1	210
A2	56	4	224
A3	28	8	224

The production of sub-products in the company is influenced by the current stock levels of parts. If the stock of parts is sufficient, no additional production is needed. However, if parts are insufficient, production is scheduled to address the shortage. The decision on how much sub-product to produce is largely based on the PPIC's intuition, aiming to meet customer demand while balancing safety stock calculations. For example, if the demand for sub-product A is 30 sets and the company already has 119 sets in stock, no production is necessary as the safety stock requirement is 80 sets. Conversely, if sub-product D has a safety stock requirement of 100 sets but only 79 sets remain after covering the demand, production is needed to make up the shortfall. Currently, there is no clear calculation or sequence for production, and the process is based on the PPIC's intuition, which can lead to inefficiencies, particularly since only one production line is available.

Lastly, the current part's production is not calculated basing on the required amount of the sub product from the PBS rather in a fixed amount that has been specified basing on the number of parts produced from the raw material (1 block of Styrofoam). Table 5 shows an example of the calculation. For instance, a production of 10 sets of sub product A is required. Referring to figure 2 it requires 20, 50 and 100 sets of part A1, A2 and A3 respectively. Therefore, the required production is only once for each part. However, the company has set a fix amount of production of each part which is shown in the 'Sets Produced' column in table 3. The remaining will then be placed in their inventory.

Table 5: Company's Production Planning from 1 February to 4 February

Sub-Product (set)	Date	1-Feb	2-Feb	3-Feb	4-Feb
A	Total Delivery	30	20	20	-
	Stock	149	119	99	79
	Balance	119	99	79	79
	Production	0	0	0	0
B	Total Delivery	20	20	0	20
	Stock	49	82	62	62
	Balance	29	62	62	42
	Production	53	0	0	0
C	Total Delivery	35	15	-	-
	Stock	49	15	19	19
	Balance	14	0	19	19
	Production	1	19	0	0
D	Total Delivery	3	47	50	50
	Stock	82	138	91	103
	Balance	79	91	41	53
	Production	59	0	62	0

2.2.4. Improve

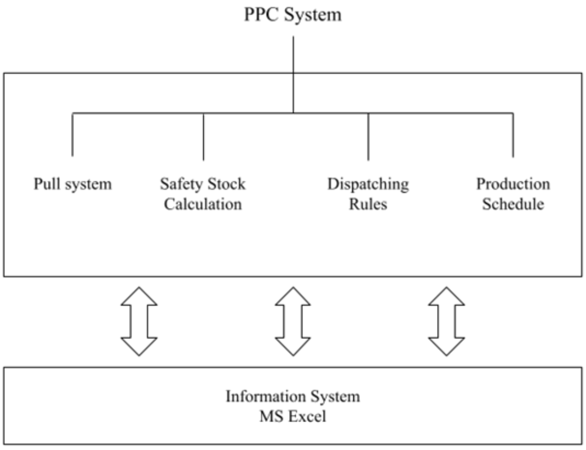

Figure 8: Proposed Improved PPC System

This research focuses on the design and enhancement of the Production Planning and Control (PPC) system within a packaging manufacturer. Although PPC encompasses numerous components, this study concentrates on specific aspects illustrated in Figure 8. Building on the analysis phase, four key actions are planned for the improvement phase, guided by data from the previous phase.

The first action involves proposing a new production strategy to address the current challenges with parts inventory and safety stock management. This strategy aims to optimize inventory levels and ensure adequate safety stock. Therefore, a new PPC system policies is proposed in this study.

The step-by-step of the policies will be divided into 3 phases namely implementation, monitoring and reporting. The production manager should ensure that the workers are well-trained and is suitable for the assigned responsibilities to avoid misconduct and in order for the experiment to run smoothly.

Implementation Phase:

1. Receive Purchase Orders:
    - Collect and list all customer orders based on their due dates.
2. Calculate Safety Stock:
    - Calculate safety stock using the provided formula.
    - Adjust the safety stock level monthly based on demand variations.
3. Determine Assembly and Packing Jobs:
    - Use Just-in-Time (JIT) theory to schedule assembly and packing tasks.
    - Identify the start of assembly based on available resources.
4. Plan Parts Production using MPS:
    - Input customer orders into the Master Production Schedule (MPS).
    - MPS will calculate required parts, deficit, and production frequency.
    - Monitor inventory levels and production requirements daily.
5. Sequence Jobs Based on EDD and SPT:
    - Prioritize tasks using Earliest Due Date (EDD) and Shortest Processing Time (SPT) criteria.
6. Capacity Planning:
    - Calculate daily and average operator requirements using capacity planning formulas.
    - Adjust the number of operators needed based on calculated demands.
7. Assign Jobs to Machines:
    - Allocate production tasks to specific machines based on job sequence and machine capabilities.

8. Visualize Schedule with Gantt Chart:
    - Create a Gantt chart to visualize the scheduling of assembly, packing, and parts production.

Monitoring Phase:

1. Daily Production Monitoring:
    - Track actual production output against the planned schedule.
    - Record any deviations from the schedule and analyze root causes.
    - Ensure inventory levels are maintained as per the safety stock calculations.
2. Capacity Utilization Monitoring:
    - Regularly check operator capacity utilization rates.
    - Adjust work assignments based on real-time demand and capacity data.
3. Job Sequencing Monitoring:
    - Verify that jobs are being executed in the correct sequence according to EDD and SPT.
    - Address any delays or re-sequencing needs promptly.

Reporting Phase:

1. Daily Production Report:
    - Compile daily reports on production output, inventory levels, and capacity utilization.
    - Include a summary of any issues encountered and corrective actions taken.
2. Weekly Performance Review:
    - Summarize weekly production data, highlighting trends in efficiency, capacity utilization, and order fulfilment.
    - Present this report to management with recommendations for any necessary adjustments.
3. Monthly Operational Review:
    - Provide a comprehensive report that includes key performance indicators (KPIs) such as production efficiency, inventory turnover, and lead times.
    - Conduct a review meeting to discuss performance against targets and strategize for the upcoming month.

The second action focuses on implementing a refined safety stock calculation. This calculation will assist the packaging manufacturer in minimizing excess safety stock, thereby reducing holding costs and improving inventory efficiency. The safety stock calculation is based on a safety stock formula developed by (Becker et al., 2013) and its elaborated in equation 2.

Safety Stock Calculation:

$$SSL = SF(SL) \times \sigma_D \times \sqrt{TRP} \qquad (2)$$

SSL : Safety Stock Level
SF : Safety Factor
SL : Service Level
σ_D : Standard Deviation of Demand
TRP : Lead Time

Table 6: Sample of Assembling and Packing Jobs

Sub Product	**Assembling and Packing Jobs for 1 February**							
	Job	***Process***	***Amount (Sets)***	***Time (Mins)***	***Delivery Date***	***Due Date***	***Start of Assembly***	***Production Due Date***
A	1	AS	30	60	1-Feb	30-Jan	27-Jan	26-Jan
	2	PK		45				
B	3	AS	20	80				
	4	PK		40				
C	5	AS	35	245				
	6	PK		87.5				
D	7	AS	3	9				
	8	PK		4.5				

Note:
AS = Assembling
PK = Packing
DD = d-2
SD = DD-TD
PD = SD-1
Notation:
DD : Due date of assembling and packing
d : Delivery Date
SD : Start of assembling and packing
PD : Production due date
TD : Total time required for completing all jobs in a certain delivery date

The third action introduces the application of dispatching rules to enhance the sequencing of daily production tasks. These rules will help streamline production processes and improve operational efficiency. The assembling and packing jobs are based on the Just in Time (JIT) theory to help the company produce the right sub product at the right amount and at the right time. Table 6 shows a sample of assembling and packing Jobs planning for a day. Here, the required time to complete the assembling and packing jobs and the available working time is considered to help determine the start of assembly beforehand. In this research, the parts are required to be available one day before the start of the assembly and packing. Unlike in parts production, in assembling and packing there is only one task for either of the two. In other words, only the jobs are considered. After determining all the jobs for both parts production and assembling and packing, the jobs will be sequenced based on the dispatching rules. In this research, the combination rule will be used. For the processing time-based rules, it will be based on the previous research done by Kaban in 2012. From his research, it shows that the Shortest Processing Time (SPT) rule works best among the other processing time-based rules. As for the due date-based rules, the packaging manufacturer demanded to produce the products that has the earliest due date.

Table 7: Sequenced Assembling and Packing Jobs

Sub Product	***Job***	***Pro-cess***	***Time (mins)***	***Deliv-ery Date***	***Due Date***	***Start of Assembly***
D	8	PK	4.5	60	1-Feb	30-Jan
D	7	AS	9	45		
B	4	PK	40	80		
A	2	PK	45	40		
A	1	AS	60	245		
B	3	AS	80	87.5		
C	6	PK	87.5	9		
C	5	AS	245	4.5		

Table 8: Sequenced Parts Production Jobs

Jobs	**Sequenced Parts Production Jobs**				
	Parts	***Total Time (Mins)***	***Frequency***	***Delivery Date***	***Due Date***
4	B1	67.5	1	1-Feb	26-Jan
8	B5	86.5	2	1-Feb	26-Jan
9	B6	91.5	3	1-Feb	26-Jan
11	C2	105.5	1	1-Feb	26-Jan
3	A3	158.5	2	1-Feb	26-Jan
12	C3	213	3	1-Feb	26-Jan
10	C1	214.5	3	1-Feb	26-Jan
13	C4	307.5	3	1-Feb	26-Jan

The chosen rules will then be implemented into the jobs that has been determined beforehand. Table 7 shows an example of the sequenced assembling and packing jobs based on the earliest due date and shortest processing time (EDD & SPT). The sequencing of parts production is similar to the assembling and packing job sequencing. Table 8 shows an example of the sequenced parts production job. In here the earliest due date still refers to the delivery date not the due date of production.

The fourth and final action involves developing a production schedule in the form of Master Production Schedule (MPS) to support production sequencing and daily parts inventory tracking. The MPS will facilitate the creation of an effective production Schedule (Table 10), which will be supported by a Gantt chart (Figure 9). This comprehensive approach ensures that production is well-organized and responsive to demand. The production Schedule consists of capacity planning, machine jobs, and parts production.

Capacity planning is the calculation of the number of human resources needed to complete all the jobs on time and fulfill customer demand. In this research, the capacity planning calculation will refer to how the company calculate its capacity. It depends on the total time required each day for producing, assembling, and packing of the sub products as the required number of human resources is the average of the number of human resources per day. Table 9 shows an example of capacity planning for a month (February).

Table 9: Capacity Planning for February

Day	**Capacity Planning for February**			
	Date	***Total Demand (in minutes)***	***Time Available (minutes)***	***Required Operators (persons)***
Thu	26-Jan	1244.5	485	3
Fri	27-Jan	1631	390	5
Sat	28-Jan			
Sun	29-Jan			
Mon	30-Jan	544	485	2
Tue	31-Jan	817.5	485	2
Wed	1-Feb	1376	485	3
Thu	2-Feb	1281.5	485	3
Fri	3-Feb	330	390	1

Day	**Capacity Planning for February**			
	Date	***Total Demand (in minutes)***	***Time Available (minutes)***	***Required Operators (persons)***
Sat	4-Feb			
Sun	5-Feb			
Mon	6-Feb	353	485	1
Tue	7-Feb	140	485	1
Wed	8-Feb	35	485	1
Thu	9-Feb	684.5	485	2
Fri	10-Feb	466	390	2
Sat	11-Feb			
Sun	12-Feb			
Mon	13-Feb	835.5	485	2
Tue	14-Feb	658	485	2
Wed	15-feb	693.5	485	2
Thu	16-Feb	1525	485	4
Fri	17-Feb	1642.5	390	5
Sat	18-Feb			
Sun	19-Feb			
Mon	20-Feb	616.5	485	2
Tue	21-Feb	190	485	1
Wed	22-Feb	827.5	485	2
Thu	23-Feb	1140	485	3
		Average		3

In this research, the days that have a higher labor than the average can be assumed that it is covered with the use of sub-contractors or overtime. In the company, overtime can be two ways:

- Weekdays = max 1 hour after 17.00 or finish time.
- Weekends = max 1 full-day work, minimum half-day.

The company has set the working minutes by the following details:

- Monday – Thursday : 485 minutes
- Friday : 390 minutes
- Weekends (if necessary):
  (minimum half-day of 485 minutes, max full day of 485 minutes)

Table 10: Master Production Schedule Sample for Production Date of 1st Feb and Due Date 4th Feb

J	P	Amount Produced (Sets)	Amount Produced (Pcs)	Required Amount (Sets)	Required Amount (Pcs)	Initial Inventory (Pcs)	D	F	P	Final Inventory (Pcs)	Total Setup Time (Mins)	Process Time (Mins)	Total Process Time (Mins)	Total Time (Mins)
1	***A1***	210	424	0	0	410	0	0	0	410	30	125	0	0
2	***A2***	56	224	0	0	160	0	0	0	160	31.5	128	0	0
3	***A3***	28	280	0	0	140	0	0	0	140	22.5	68	0	0
4	***B1***	28	56	20	40	13	-27	1	56	29	22.5	45	45	67.5
5	***B2***	96	96	20	20	385	0	0	0	365	25.5	71	0	0
6	***B3***	90	92	20	20	229	0	0	0	209	25.5	81	0	0
7	***B4***	75	150	20	40	75	0	0	0	35	28.5	95	0	0
8	***B5***	28	24	20	40	20	-20	1	24	4	16.5	35	35	51.5
9	***B6***	9	72	20	160	40	-120	2	144	24	16.5	25	50	66.5
10	***C1***	15	60	0	0	40	0	0	0	40	25.5	63	0	0
11	***C2***	25	102	0	0	69	0	0	0	69	28.5	77	0	0
12	***C3***	16	66	0	0	64	0	0	0	64	21	64	0	0
13	***C4***	14	57	0	0	28	0	0	0	28	22.5	95	0	0
14	***C5***	40	160	0	0	37	0	0	0	37	30	82	0	0
15	***C6***	35	140	0	0	122	0	0	0	122	31.5	99	0	0
16	***D1D2***	14	57	100	200	10	-190	4	228	38	22.5	72	288	310.5
17	***D3***	56	112	50	100	64	-36	1	112	76	25.5	71	71	96.5
18	***D4***	28	56	50	100	25	-75	2	112	37	22.5	78	156	178.5
19	***D5***	28	56	50	100	25	-75	2	112	37	30	83	166	196
20	***D6***	49	98	50	100	94	-6	1	98	92	27	87	87	114

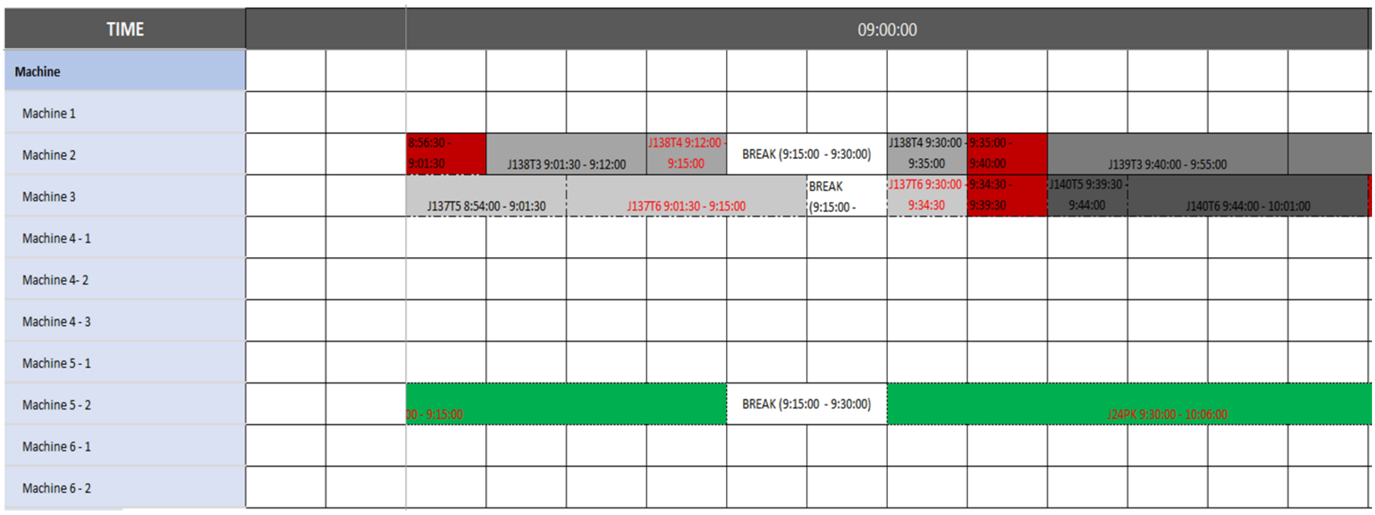

Figure 9: Sample of Gantt Chart

All these activities will be integrated and managed using Microsoft Excel, which will serve as the central information system for the PPC improvements. This integration will provide a robust framework for enhancing production planning, scheduling, and inventory management within the packaging manufacturer.

3. Result and Discussion

3.1. Comparison of Results

There will be several perspective taken in comparing the results by using gap analysis and the effectiveness of the proposed system to the packaging manufacturer. Before and after results will be compared and the difference will be measured in percentage. The metrics that is used to assess the effectiveness of the system is through the carrying cost and holding cost in the company before and after the system is applied.

The first perspective is inventory on hand. Since data for daily parts inventory on hand is not available, the researcher had created the current parts inventory basing on the historical data. Table 11 shows an example of the current parts inventory data of sub product A. For the parts inventory, two measurements will be taken which are the total final parts inventory on hand and the average daily parts inventory. Table 12 shows the current total final parts inventory on hand and average daily parts inventory. The word final in this case refers to the last date of delivery which in this case is 28 February.

Table 11: Current Daily Parts Inventory of Sub Product A

28-Feb	Current Daily Parts Inventory of Sub Product A			
	A1	*A2*	*A3*	*Sub Total*
Initial Stock (pcs)	104	444	10	
Required (sets)	0	0	0	
Required (pcs)	0	0	0	
Production(pcs)	0	0	0	
Final Stock (pcs)	**104**	**444**	**10**	**558**

Table 12: Current Total Final Parts Inventory on Hand and Average Daily Parts Inventory

Date	Total Final Parts Inventory and Average Daily Inventory				
	Sub Product A Parts (pcs)	*Sub Product B Parts (pcs)*	*Sub Product C Parts (pcs)*	*Sub Product D Parts (pcs)*	*Total (pcs)*
28-Feb	558	960	228	243	1989
Average					**2697,143**

Table 13: Difference in Amount of Parts Inventory

Measurement	Difference in Amount of Parts Inventories		
	Before (pcs)	*After (pcs)*	*Difference (%)*
Total Final Parts Inventory	1989	1225	**38%**
Average Daily Inventory	2697	1680	**37%**

In the proposed idea of the PPC system, it can be seen from the Master Production Schedule that the total final parts inventory of the parts is 1225 (pieces). Furthermore, the average daily parts inventory obtained from the proposed PPC system is 1680 (pieces). Table 13 shows the difference in the measurement before and after implementation of the proposed PPC system. A difference of 38% and 37% for total final parts inventory and average daily inventory on hand respectively.

The second análisis that can be discussed is from the perspective of safety stock calculation. Using the proposed safety stock calculation and the current safety stock calculation, the difference can be calculated between the two and is shown in table 14. A difference of 75%, 83%, 77% and 72% for safety stock of sub product A, B, C and D respectively.

Table 14: Difference in Amount of Safety Stock

Sub Product	Difference in Amount of Safety Stock		
	Before (sets)	*After (sets)*	*Difference (%)*
A	80	20	75%
B	120	22	83%
C	70	16	77%
D	100	28	72%

The economic analysis of holding cost will be based on the mass of the parts or the sub products. Assuming the carrying cost is the cost per gram of raw material multiplied by the mass of the part, the calculations will be as follows.

$$Carrying\ Cost = Cost\ per\ gram \times Mass \quad (3)$$

Table 15: *Mass and Cost of Raw Material*

Item	Mass of Raw Material and Cost	
	Mass (gr)	*Cost (Rp)*
Raw Material	13.500	950,000

From table 15, therefore the cost per gram will be Rp.70,370. From that value, the carrying cost of parts can be determined.

Table 16: Carrying Cost of Parts and Sub-Products

Sub Product	**Carrying Cost of Parts**	
	Parts	***Carrying Cost (Rp)***
A	A1	2,956
	A2	11,400
	A3	29,204
Total		43,559
B	B1	22,096
	B2	7,037
	B3	5,630
	B4	7,670
	B5	23,504
	B6	55,170
Total		121,107
C	C1	42,222
	C2	28,711
	C3	18,859
	C4	27,585
	C5	8,093
	C6	5,137
Total		13,607
D	D1D2	14,215
	D3	9,430
	D4	13,933
	D5	16,185
	D6	10,274
Total		64,037

From the carrying cost of each part, the holding cost can be calculated.

$$Holding\ Cost = Carrying\ Cost \times No.of\ Parts \quad (4)$$

Table 17: Total Final Parts Inventory Holding Cost Before and After

Parts	**Total Final Parts Inventory Holding Cost**			
	Before (pcs)	***After (pcs)***	***Holding Cost Before (Rp)***	***Holding Cost After (Rp)***
A1	104	312	307,378	903,834
A2	444	12	5,061,600	136,800
A3	10	50	292,037	1,460,185
B1	117	5	2,585,267	110,481
B2	297	185	2,090,000	1,301,852
B3	141	29	793,778	163,259
B4	49	125	375,848	958,796
B5	84	4	1,974,311	94,015
B6	272	24	15,006,341	1,342,089
C1	30	40	844,444	1,688,889
C2	49	75	1,406,844	2,153,333
C3	36	28	678,933	528,059
C4	4	13	110,341	358,607
C5	17	57	137,574	461,278
C6	102	102	523,978	523,978
D1D2	29	20	412,230	284,296
D3	104	6	980,681	56,578
D4	9	23	125,400	320,467
D5	9	23	145,667	372,259
D6	92	92	945,215	945,215
Total			34,797,867	14,164,570

Lastly, the difference between before and after implementation can be calculated.

Table 18: Total Final Parts Inventory Holding Cost Difference

Total Final Parts Inventory Holding Cost Difference			
Before (Rp)	***After (Rp)***	***Difference (Rp)***	***Difference (%)***
34,797,867	14,164,570	20,633,296	59

Not only the difference of holding cost of parts will be calculated but the holding cost of the safety stock as well.

Table 19: Total Safety Stock Holding Cost

Sub Product	**Safety Stock Holding Cost**			
	Before (sets)	***After (sets)***	***Holding Cost (Before) – in Rupiah***	***Holding Cost (After) – in Rupiah***
A	80	20	3,484,741	871,185
B	120	22	14,532,889	2,664,363
C	70	16	9,142,519	2,089,719
D	100	28	6,403,704	1,793,037
Total			33,563,852	7,418,304

Table 20: Safety Stock Holding Cost Difference

Safety Stock Holding Cost Difference			
Before (Rp)	***After (Rp)***	***Difference (Rp)***	***Difference (%)***
33,563,852	7,418,304	26,145,548	77

From the calculations, it shows a decrease of 59% in the holding cost of the total final parts inventory and 77% in the holding cost of the safety stock.

3.2. Control

The control phase is consisted of two components which are socialization and assessments of new PPC system. The control phase here is used in maintaining the proposed PPC system. socialization is intended for explaining and demonstrating the proposed PPC system to the packaging manufacturer and collecting any feedbacks given by the production department. Furthermore, the socialization also ensures that the production department understands the new design of the PPC system and the outcomes that can be obtained.

The assessment will be done after the proposed PPC system is applied in the production. Assessments are done to evaluate the results of the proposed PPC system when applied and ensuring the expected outcomes of the new design of the PPC system are met.

4. Conclusion

This research focuses on enhancing the production planning and control (PPC) system in a packaging manufacturing company, addressing the current challenges of high safety stock and parts inventory, as well as production decisions based on intuition rather than data-driven methods. The proposed solution encompasses several components, including minimizing safety stock, reducing parts inventory, and optimizing production scheduling.

The new PPC system adopts a demand-oriented or pull production strategy, aiming to decrease safety stock and parts inventory. A safety stock calculation is utilized to determine appropriate safety stock levels. Production of parts is driven by individual parts and customer demand rather than fixed amounts, supported by a Master Production Schedule (MPS) to track daily parts inventory. The production process is divided into two phases: parts production using the make-to-stock theory and assembling and packing using the Just-In-Time (JIT) theory. Dispatching rules are employed to schedule production effectively.

The results of the proposed PPC system demonstrate significant improvements. The new production strategy meets customer demands on time and reduces safety stock utilization. Parts inventory decreases by up to 38% in total final inventory and 37% in average daily parts inventory. Safety stock is reduced substantially for various sub-products (A, B, C, D). Economically, the proposed changes lead to a 59% reduction in parts inventory holding costs and a 77% reduction in safety stock holding costs.

In summary, the research showcases that the new PPC system enhances production efficiency by reducing safety stock, parts inventory, and associated holding costs while meeting customer demands promptly. The study recommends that the packaging manufacturer adopt the new pull production system to minimize parts inventory on hand. The proposed production strategy (make-to-stock and JIT) helps in minimizing safety stock utilization, allowing for lower safety stock levels. Implementing a safety stock calculation is crucial for controlling safety stock amounts. Clear production planning should be implemented to avoid reliance on intuition-based decisions.

For future research, it is advised to develop or use software for automatically generating Gantt charts, as manual creation is time-consuming. Additionally, implementing time studies is essential for a more accurate production schedule. Further research using Operational Research techniques is recommended to enhance decision-making and optimize the complex production system.

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AUTHORS METADATA

I. First Author:

1. First name : Fransiskus
2. Middle Name : Dimas Adrian
3. Last Name : Brahmantyo
4. E-mail : fransiskus.brahmantyo@student.sgu.ac.id
5. Orcid ID :
6. Orcid URL :
7. Affiliation : Swiss German University
8. Country : Indonesia
9. Bio Statement : Industrial Engineering, Faculty of Engineering and Information Technology
10. Phone Number :

II. Second Author*:

1. First name : Ivan
2. Middle Name :
3. Last Name : Kurniawan
4. E-mail : ivan.kurniawan@sgu.ac.id
5. Orcid ID : 0000-0003-4924-4770
6. Orcid URL : https://orcid.org/0000-0003-4924-4770
7. Affiliation : Swiss German University
8. Country : Indonesia
9. Bio Statement : Industrial Engineering, Faculty of Engineering and Information Technology
10. Phone Number :

III. Third Author:

1. First name : Triarti
2. Middle Name :
3. Last Name : Saraswati
4. E-mail : triarti.saraswati@sgu.ac.id
5. Orcid ID :
6. Orcid URL :
7. Affiliation : Swiss German University
8. Country : Indonesia
9. Bio Statement : Industrial Engineering, Faculty of Engineering and Information Technology
10. Phone Number :