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Evaluation Batch Process Scheduling for Single Campaign in FMCG Industry

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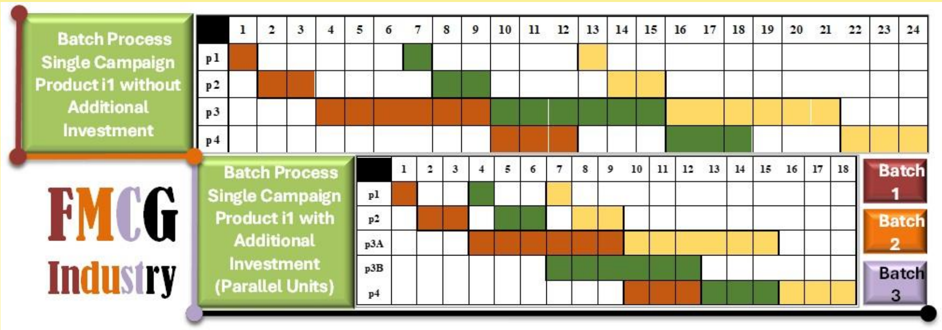
***Abstract*—** The Fast-Moving Consumer Goods (FMCG) sector plays a pivotal role in meeting daily consumer requirements. Efficient manufacturing and revenue generation are of paramount importance. The industry adopts a batch-processing approach to maintain adaptability and responsiveness to evolving market needs. A critical element in this process is the evaluation of batch scheduling, especially the batch cycle time of the products, a key factor with a substantial impact on production efficiency and profitability. This research delves deep into the complexities of batch scheduling methods between overlapping batches and parallel units for limiting steps, especially single-product campaigns in terms of its benefit towards production efficiency and company profitability. In the end, it illustrates the consequences of optimal scheduling on production time and income, highlighting the potential for significant improvements or downwards within the applied method through sensitivity analysis, which could give the FMCG industry more careful consideration in strategizing its future planning production.



***Keywords*—** Batch Cycle Time; Batch Processing; Evaluation; FMCG; Revenue; Single Product Campaign

I. Introduction

The growth in population and the economy has driven an increased demand for everyday household necessities. To meet the high demand in the market, the Fast-Moving Consumer Goods (FMCG) industry, characterized by the production of goods required for daily life with rapid turnover, must efficiently shorten production times and maximize profitability [1]. The FMCG (Fast Moving Consumer Goods) industry encompasses a vast array of consumer products, from food and beverages to personal care and household essentials. Globally, it reached a market value of $11,490.9 billion in 2021, with projections suggesting it will surge to $18,939.4 billion by 2031, boasting a 5.1% Compound Annual Growth Rate (CAGR) from 2022 to 2031. Over the past decade, this sector has sustained robust growth, driven by factors like the rise of experiential retail, population growth, and increased internet and social media usage [2], [3]. In Indonesia, the FMCG industry is thriving, showing resilience and growth despite pandemic challenges and inflation. The third quarter of 2022 witnessed a 5.9% year-on-year increase in the country's FMCG market value, solidifying its position as a cornerstone of the nation's economy. Indonesia's FMCG sector not only demonstrates growth but also remains a key driver of the country's economic landscape, promising a bright future [4]. With thousands of orders to fulfill, FMCG companies rely on the supply and demand concept to ensure there is no surplus supply that could negatively impact pricing or insufficient production capacity leading to shortages. Such circumstances could diminish the market potential for FMCG companies, ultimately affecting their Dispatch Rate (a key indicator of how well a company can deliver finished products according to customer orders) [1].

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The supply chain, a pivotal component of the FMCG industry, is integral and encompasses five key departments: supply planning, procurement, manufacturing processes, logistics, and customer handling, each playing a unique role in ensuring efficient operations and customer satisfaction [5]. Within this intricate framework, the manufacturing stage stands out as a critical focal point, with a primary focus on batch process scheduling. The FMCG industry is renowned for its enduring growth, largely attributed to the popularity of mass brands. What sets this industry apart is not only its remarkable agility but also the remarkable diversity in the products it offers. These products vary in type, packaging, and size, catering to a wide range of consumer preferences. To sustain this diversity, FMCG manufacturing systems commonly rely on batch processing. This method involves the strategic planning of manufacturing operations to create product components in batches, as opposed to a continuous flow. This approach aligns perfectly with the need to address fluctuating market demands, changing consumer preferences, and the consistent demand for specific products [6], [7]. In the FMCG sector, time is a precious resource, and its efficient management is essential. This is particularly true when dealing with numerous orders that must be fulfilled efficiently and on time. The effective management of time plays a critical role in optimizing production capacity and ensuring customer satisfaction [8].

Within this context, the focal point revolves around the realm of batch process scheduling, a method involving the strategic planning of manufacturing operations to produce finished product components in groups, or "batches," as opposed to a continuous or uninterrupted flow [7]. Batch processing scheduling can be categorized into two primary types: single-product batch plants, dedicated to the production of a single product type, and multiple-product batch Plants, responsible for producing two or more distinct products [9]. Multiple Product Batch Plants further subdivide into flowshop plants, characterized by a system in which all products undergo the same sequence of operations, often referred to as a "multi-product plant," and jobshop plants, which operate under a system where not all products require every stage in the same sequence, sometimes referred to as a "multi-feed plant" [10].

In the realm of facilitating batch processing, the creation of a Gantt chart is essential to depict each process, makespan, and batch cycle time. Makespan, a fundamental metric in production scheduling, quantifies the total time required to complete a specific number of batches, offering valuable insights into the efficiency of manufacturing operations [11]. Conversely, batch cycle time, another critical parameter, represents the time interval between the production of successive product batches. This temporal gap plays a pivotal role in managing the flow of products within the production process, ensuring smooth transitions and minimizing downtime [12]. The optimization of batch processing for single products involves the implementation of various techniques. Sequential production schedules dictate the execution of each batch only after the preceding one is completed, maintaining a linear flow of production activities [13]. Overlapping batches, on the other hand, involve aligning tasks based on the duration of the longest process, thus minimizing idle time and enhancing efficiency [14] [15]. Parallel units, a complex but effective approach, entail the simultaneous processing of multiple jobs within a single batch, often accomplished through the utilization of multiple machines or resources operating in parallel [16]. Intermediate storage practices, a strategic component of batch processing, involve the temporary holding or storage of materials between different processing stages, streamlining production flow and preventing bottlenecks [17]. These techniques and considerations in batch processing scheduling play a pivotal role in optimizing production efficiency and resource utilization within the FMCG industry, making them a subject of significant interest in this study.

Multiple researchers have explored issues related to batch scheduling. For instance, Liao and Huang (2011) devised a batch scheduling model for a flow shop configuration housing two batch processing machines equipped with buffers of unlimited capacity and their primary aim was to minimize makespan [18]. In a distinct context, Rossi et al. (2013) crafted a hybrid model for a flow shop within a sterilization facility. Their goal was twofold: reducing both makespan and the count of tardy jobs. The focus on makespan stemmed from its impact on idle time, machine utilization, and efficiency improvement [19]. While for the single-product case with the parallel method, there are several related studies, for example, by Fowler and Monch (2022) and Druetto et al. (2022), where the authors discuss the challenges and opportunities of parallel batch scheduling and offer a concise overview of the literature on single-machine parallel batch scheduling problems with total completion time as a performance measure [16], [20]. However, most of that research predominantly utilizes a maximum of two machines, concentrating on minimizing makespan or in terms of dealing with total completion time as a performance measure and minimizing energy consumption. Therefore, this study addresses the scenario when there are more than two machines and explores the resultant effects within a process, both concerning the resulting makespan and focusing on batch cycle time.

This study will focus on evaluating production time efficiency for a single product to increase profitability. The difference in total production between the evaluated schedules will determine the evaluation result. It can be supported and expedited by Microsoft Excel for mathematical and graphical representation. The elements contained in the calculation of the factory economic evaluation include the amount of capital required or Capital Expenditure (CAPEX), expenses from running a business that is not directly related to the production of goods or services sold or operational expenditure, gross revenue, which is total revenue generated by the plant from its main business activities before deducting other expenses, net profit, which is a fundamental financial evaluation that represents the amount of money a company or individual earns after deducting all fees, taxes and interest from its total income or gross income [21]. Lastly, sensitivity analysis is a crucial aspect of economic chemical plant design and is used to identify the parameters that have a significant impact on project viability over the expected range of variation of the parameter. The purpose of sensitivity analysis is to optimize a process, maximize project value and plant performance, minimize project cost, and facilitate the selection of the best components. Sensitivity analysis is also used to identify the risk involved in making judgments on the forecast performance of the project. The results are usually presented as plots of economic criterion. Researchers have applied sensitivity analysis methodology based on continuation techniques to chemical engineering processes [22]. Thus, the expected outcome of this research is to explore strategies for evaluating the efficiency of time and cost using sensitivity analysis in a current FMCG factory for a single product, including one of them being the incorporation of equipment dedicated to reducing processing time, particularly for the lengthiest operations. This research also delves into the equations employed to determine batch cycle time and makespan for single products, both overlapping and parallel units, along with their impact on the company's economic condition using the sensitivity analysis.

II. Method

The calculation scope will cover the case of a single campaign manufacturing system in a hypothetical *established* factory with a batch process type of production. Additionally, the calculation will use a flowshop step process which means that it can't change the process order sequence and requires all stages to be fulfilled. Furthermore, a clear interpretation of the batch processing schedule must be made. According to the Chemical Process Design & Integration by Robin Smith (2016) Makespan is the total time required to produce a certain number of batches. Meanwhile, batch cycle time is the time interval between successive batches of product being produced and it must be at least as long as the longest step. It means that 1 batch production is where the raw material must go through all 4 stages to be completed. Here is the hypothetical case for 1 product (i1) with 4 stages (p1, p2, p3, & p4) to produce it.

TABLE 1.
CYCLE TIME CONFIGURATION AND ITS PROCESS

Product	p1	p2	p3	p4
i1	1 hours	2 hours	6 hours	3 hours

Based on the Systematic Method of Chemical Process Design by Lorentz T. Bigler, there are several methods for determining the batch processing schedule that will influence the value of makespan and batch cycle time. This research will use "Overlapping Concept", which is a method where subsequent batches are started as soon as the appropriate equipment becomes available [23]. This approach aims to safeguard raw materials during production and ensure high utilization of batch process design by reducing the batch cycle time considerably. The step with the longest time limits the batch cycle time, therefore based on the concept above, we divide it into 2 scenarios, in which case A consists of overlapping batches without any additional parallel equipment and case B consists of overlapping batches with an additional parallel equipment in longest time process or it might be called as parallel units for the limiting step. In this study, we will dive deep into the implications from time efficiency to the economic benefits of adding new equipment in the longest batch process time during a certain production. In order to check the production time efficiency between the 2 scenarios (case A & B), makespan and batch cycle time values must be obtained.

First is the case A calculation. In order to calculate batch cycle time in overlapping batches without any additional parallel equipment in a single campaign. Based on Robin Smith, the value can be obtained by subtracting the end time of the 1st cycle batches and the end time of the 2nd cycle batches. However, the BCT calculation for case A can be simplified as shown.

$$\text{Batch Cycle Time (BCT)} = \text{pT} \,/\, \text{eT} \qquad (1)$$

For *BCT* as the batch cycle time value in hours, *pT* as the longest process time in the production stage in hours, and *eT* as the amount of equipment in the longest process stage in hours. It's continued to the makespan value calculation which stated above as the total time required to produce and it can be simplified to this equation for case A as shown below.

$$\text{Makespan A (MA)} = (\text{BCT} * \text{b}) + (\textstyle\sum_{\text{n}} \text{p} - \text{pT}) \qquad (2)$$

For *MA* as the makespan value for case A depending on total batches in hours, *b* as total batches that wants to be produced in a certain amount of time in numeric $\sum_n p$ as the total time of all stage that needs to be done in hours.

Second is the case B calculation. For the BCT value in case B, equation 1 can be used as well. However, for the makespan value, the equation has a slight change in the equation as shown below,

$$\text{Makespan B(MB)} = (\text{BCT} * (\text{b} + 1)) + (\textstyle\sum_{\text{n}} \text{p} - \text{pT}) \qquad (3)$$

By getting all the data and targeting the makespan for both A and B to 168 hours, or equivalent to 1 week, the maximum total cycle of production in 1 week can be found by using the goal seek method.

Besides the production time efficiency, the economical calculations must be done with several established assumptions. The additional investment for 1 piece of equipment in the longest batch process time is IDR 261,000,000 (assumption based on estimated price in Matche on jacketed & agitated Stainless Steel 304 Reactor with volume of 22 gallons and pressure maximum up to 25 atm) with 6% interest rate with due payment in 5 years. In the book Plant Design and Economics for Chemical Engineering by Klaus D. Timmerhaus (2003), future value can be calculated in this equation below,

$$F = P * (1 + i)^n \quad (4)$$

For *F* as the future value of the equipment investment in IDR, *P* as the present value of the equipment investment in Rupiah (Rp), *i* as the interest rate per year of the equipment in percentage, and n as the interval year between present and future value in Years. In order to create an objective comparison between the batch process with no and with additional equipment, the underlying assumption is that the factory runs 24 hours in 7 days. 1 cycle batches produced 100 liters, with 1 liter equivalent to the total sales of IDR 6,250 in Indonesian currency. Gross revenue can be found by reducing the generated sales with the cost of production. The cost of production is separated into 2 parts which is the cost of material that is counted around IDR 3,750 per liter production with other costs (marketing, maintenance, etc) counted around 20% of the total sales. Here is the formula calculation below,

$$\text{Gross Revenue (GR)} = \Big((b * 100 * S * 4) - \Big((b * 100 * CM * 4) + \big((b * 100 * S * 4) * CO\%\big)\Big)\Big) \quad (5)$$

For *GR* as the total gross revenue in 1 month that is generated in IDR, *S* as the sales per liter production in IDR, *CM* as the cost of material per liter production in IDR, and *CO%* as the cost of others in the percentage of total sales. Because of the due payment in 5 years, we need to calculate the total net revenue in 5 years by converting the gross revenue in 1 month to 5 years by multiplying it by 12 months and 5 years. Furthermore, for case A, there is no additional investment in equipment, therefore gross revenue is equal to net revenue, however for case B, in order to gain the net revenue, it must be subtracted with the future value of the equipment investment as shown below,

$$\text{Net Revenue (GR)} = GR - F \quad (6)$$

The study will also include sensitivity analysis to showcase how different changes in scenarios can impact the conclusion in terms of the sales per liter, cost of material per liter, and equipment cost. It will help to understand how big the impact can change the revenue that is gained based on the factor changes. The mathematical calculations will be supported by Microsoft Excel. In the end, the study objective is to help the industry in making decisions for production efficiency & profitability.

III. Results and Discussion

Based on the calculation method above, in the result of case A without any additional parallel equipment, the batch cycle time is 6 hours with the makespan for 2 cycles reaching up to 18 hours, while for the result of case B with additional parallel equipment to the longest time batch process, the batch cycle time is 3 hours with the makespan reduced to 15 hours. The additional equipment resulted in increasing productivity for the batch cycle time by around 50% and reduced the time makespan for 2 cycles by around 16.67%. It shows high efficiency in terms of reducing production time because the delay time between stages is reduced as shown below,

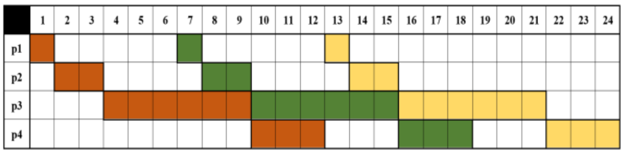

Figure 1. Batch Process Single Campaign Production Schedule i1 without Additional Equipment Investment

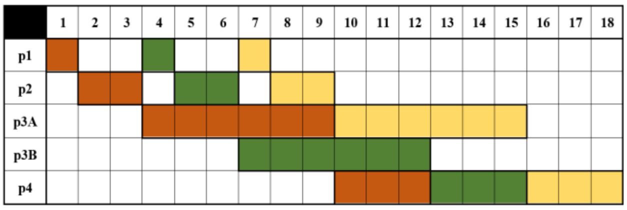

Figure 2. Batch Process Single Campaign Production Schedule i1 with Additional Equipment Investment (Parallel Units)

Notes for the Chart are that the color indicates different batches that is running in the production schedule.

The parallel units in limiting steps reduce the overall batch cycle time because while the first cycle is still running, the second cycle can start earlier while maintaining zero wait transfer. Furthermore, how the additional investment will impact the revenue. In 1 month of production, which is equivalent to 672 hours, the total cycle produced without additional equipment is around 108 cycles. With 100 liters per cycle production, the total sales in 1 month can be generated is around IDR 67,500,000 with the cost of production up to IDR 54,000,000, consists of 80% of material cost (IDR 40,500,000) & 20% for labor & electricity cost (IDR 13,500,000 with IDR 31,250 per equipment per cycle). Extending the data to 5 years, the earnings before interest, taxes, depreciation, and amortization (EBITDA) for case A (no additional equipment) could reach up to IDR 810,000,000.

While production with additional equipment can be manufactured up to 212 cycles, with the total sales in 1 month up to IDR 132,500,000. Even though production cycles go up, so is the cost of labor & electricity. By estimating the additional equipment with the same rate of labor & electricity cost per equipment per cycle, it will reach up to IDR 33,125,000. Therefore, the cost of production goes up to IDR 112,625,000. Extending the data to 5 years, the gross revenue for case B could reach up to IDR 1,192,500,000. It shows an increase of 47.22% in EBITDA generated with additional equipment. However, the question remains is the cost of equipment is worth it to be purchased or not. It can be answered by reducing the EBITDA with the cost of investment in additional equipment. By knowing the interest rate around 6% & the cost of equipment around IDR 250,000,000, the estimated future value of the equipment after 5 years is approximately IDR 334,556,394. If we reduced the revenue gained with additional equipment in 5 years by the total cost of the equipment investment, we gain an increase of revenue up to 5.92% encountered around IDR 857,943,606 for case B compared to the net revenue in case A. Current observations show that it is still worth purchasing this equipment if there is stable up-trend demand, because it's not just reducing the amount of production time efficiently, but also increasing the profitability of the industry.

However, the real world with its ever-changing market situation challenges the industry to be prepared in the worst-case scenario for a drop down. 3 factors are measured which are sales per liter, cost of material per liter, and the cost of investment. To check it, we used sensitivity analysis to navigate how price changes can increase or decrease the net revenue. The sensitivity analysis will be counted in 5 scenarios which are normal situations (0%, which means no change to the previously established assumption price) with 10% up and down (-10%, -20%, 10%, and 20%). Here is the result of the sensitivity analysis after changing the sales per liter and cost of equipment investment in Table 2 and Fig 3.

TABLE 2.
SENSITIVITY ANALYSIS RESULT BASED ON THE PARAMETERS

Sensitivity Analysis		-20%	-10%	0%	10%	20%	Slope
Sales Price per Liter	Data	IDR 5,000	IDR 5,625	IDR 6,250	IDR 6,875	IDR 7,500	4,227
	Case A:B	-100.00%	-84.46%	5.92%	36.04%	51.11%	
Cost of Material	Data	IDR 3,000	IDR 3,375	IDR 3,750	IDR 4,125	IDR 4,500	-3,985
	Case A:B	39.81%	26.78%	5.92%	-32.81%	-129.65%	
Cost of Equipment	Data	IDR 200,000,000	IDR 225,000,000	IDR 250,000,000	IDR 275,000,000	IDR 300,000,000	-0,090
	Case A:B	14.18%	10.05%	5.92%	1.79%	-2.34%	

In order to check what influence the swing of revenue is through the slope analysis. Based on the slope value, the sales price per liter has more impact on the revenue volatility, followed by the cost of material price change, and lastly the cost of equipment. From the sensitivity analysis, several outputs can be considered. First, the Sales price per liter shows that adding an investment would be great for the company's revenue growth in the ideal conditions. However, adding new equipment means more supply which drags the question on the demand side. If there isn't much demand to fulfill the production can run maximally as expected or too much supply which might decrease its own sales value, which could lead to a catastrophic impact on the revenue gained especially when the slope impact is not linear but rather impact it on an exponential level.

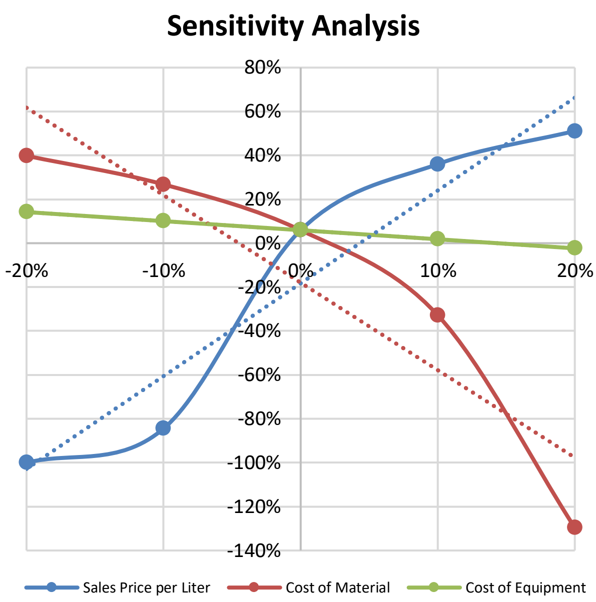

Figure 3. Sensitivity Analysis Result in Chart

Second, the cost of material per liter shows exponential impact as well even though less impactful than the sales price per liter changes. War, climate changes, government regulation, etc can change the raw material cost of certain products. Lastly, the cost of equipment only impacts on the linear level and the change doesn't seem to give any changes in revenue. In the end, the method to increase production efficiency through parallel units for the limiting step must be approached with careful consideration towards the revenue impact on the company whether the company still sees big potential for growth in production demand or not. This equipment investment will have a huge impact on the company.

IV. CONCLUSION

In the end, the decision is based on the industry real time data. The hypothetical case above is just a result in the ideal world of manufacturing where it is assumed that it can reach up to 100% production capacity and no inflation rate. For certain industries, it can be viewed as a disaster if the cost of equipment reduces the total revenue in the short term, especially if the worst scenario happens. It will impact on the stakeholder investment in the company. Probably for a more established and firm company with secure financing, could see this as a long-term investment which could boost profit in the long run with higher production and lower working time. However, it never attracted any risk. It can be noted that this is on the scale of maximum production capacity, which doesn't seem always the case due to the market changes therefore the decision to buy heavily depends on the company still trust in the product demand growth in the future ot not. In the end, this analysis can certainly become a helpful based to determine the next action of company to expand its production through new capital investment or simply focus on sustaining the product sales first.

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