Discrete system simulation application on determining the optimal amount of weekly production

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Abstract. PT. MNO produces egg trays to serve requests from 4 Distribution Centers (DC) in 4 regions, namely DC1, DC2, DC3, and DC4. Delivery of products to meet all DC requests is done once a week. Sometimes, supply shortages occur when the total weekly production and initial stock is lower than the total demand. This shortage of supply results in loss of opportunity. While in other weeks there is excess inventory which causes storage costs. Shortage or excess stock is related to the absence of production planning and determination of weekly production plans. Therefore, the optimal amount of weekly production needs to be determined using a system simulation. Simulation models are designed and translated into formulas in Microsoft Excel worksheets. While data on the number of requests is generated by using the weekly demand distribution pattern as a reference. Discrete system simulations are run by experimenting on nine levels of total weekly production. The output obtained includes the number of requests that can be fulfilled, the weekly ending stock, the number of shortage, the amount of excess stock, and the total profit. Simulation results obtained can indicate the optimal level of production.

1. Introduction
In increasing global competition, challenges arise for all types of companies. To be more successful, increased competition demands higher efficiency and faster responses. Therefore, new concepts such as logistic, inventory control, and supply chain management are increasingly important for companies. The management process must be based on faster and better decisions in responding to markets and dynamic environments as customers demand better products and faster responses [1].

Customers always demand better products with shorter and more precise deliveries at lower costs [2]. Faced with these actual demands, manufacturing companies must be competitive in various ways, including cost efficiency, quality, delivery time, and process flexibility [3]. Manufacturing companies can choose and use competitive strategies based on a combination of cost, time, service and quality. Manufacturing companies can use the right strategy to achieve competitive advantage [4].

Effective inventory management provide opportunities to create sustainable competitive advantage and enhance the competitive position of companies. This entails reduction in cost of holding stocks by maintaining just enough inventories, in the right time and the right cost to make the right amount of needed products. The high level of stock held in inventory will affect the procurement performance of the use of retained capital that affects cash flow which leads to reduced efficiency, effectiveness and distorted functionality [5].

Operational excellence in manufacturing, logistics and distribution across the entire supply chain depends on the ability of the company to serve and meet customer demands effectively, at the right time and the right amount [6]. However, with the development of new technologies, the challenges that need to be overcome are increasing and the opportunities to use simulations in supply chain management are
Simulation systems as a supporting tool in supply chain management have become increasingly attractive to many companies in recent years. By simulation, virtual supply chain networks emerged as a concept to symbolize imitation of material and information flow between manufacturing and distribution network agents.

When supply chain and logistic management becomes an urgent need, proactive planning and control processes become the main problem that must be solved [8]. Simulations can help improve the decision making process and better reaction to customer requests. But there are still challenges and obstacles that must be overcome to get better models and more accurate simulations [5].

1.1 Statement of the problem
PT. MNO is an egg tray manufacturing company that operates to meet demand from 4 marketing regions namely DC1, DC2, DC3, DC4. In each region there is one distribution center (DC) which submits weekly requests to the company’s distribution and sales center. The amount of weekly request from each DC varies from week to week. To meet all weekly requests, the company stores its daily production in the company’s distribution and sales center warehouse.

Delivery of egg trays to meet the demand from each DC is done once a week. Products (egg trays) are bound to 100 pieces per package. In this case, sometimes there is a lack of supply so it is not enough to meet demand. In this event, the company will lose the opportunity to make a profit. While in other weeks there are excess products that are stored as stock which will be used to meet demand in the following week. This excess product storage incurs storage costs. In practice, the company has not set daily and weekly production targets, and has never reviewed the optimal amount of weekly production. This problem needs to be solved by using simulation.

2. Concept, approach and method
2.1 Production strategy
Make to stock is an organization's strategy to produce products based on anticipated demand. Make to stock is the opposite of make to order where the goods are produced based on the request or the actual order from the customer. This strategy is needed to prevent lost opportunities due to out of stock and minimize excess inventory using accurate estimates. In this strategy, the product is produced based on estimated demand. Because the accuracy of the forecast will prevent lost opportunities due to out of stock and excess inventory, the problem here is how to accurately estimate demand [9].

As the economy develops, consumer income increases and demand also increases. Demand changes according to economic changes. Even if demand decreases and supply increases, inventory will be sold and turned into cash when demand recovers. Therefore, the main theme of business management today is how to predict the future based on the cycle of past demand fluctuations. In particular, the development of production and inventory management is needed to improve efficiency. For example, by establishing safety stock, optimal production target, and ordering points based on estimated demand, time lags for procurement of materials, production processes, and shipping. If demand can be accurately estimated to a certain extent, then there is no problem in making estimates of production schedules. But accuracy is generally difficult to fulfill [10].

One of the benefits of the make to stock strategy is in handling inventory so that there is no excess stock. Inventories must support a fast and efficient response to meet demand and replenish inventory, so product flow will increase and cash flow will also increase [11]. For this reason, proactive planning and control processes are the main problems that must be resolved. Excellence in carrying out operations in manufacturing and logistics along the supply chain will depend on the timely and effective translation of customer demand into production plan and material control [12, 13].

2.2 Discrete systems
A system is a simplified representation of reality. System is a general term that is often used with a loose meaning. In the real world, a system emerges as a set of connected elements. However, by defining the system as a series of selected elements, the system is simplified by implicit assumptions of time limits.
and predetermined characteristics. This simplification of space and time is important because it requires reflection, and thus, expertise in the existing reality [14].

A discrete system comes with a number of statuses that can be calculated, and can be contrasted with a continuous system. Discrete systems are often modelled graphically, where the time and state variables are two things that are often used to describe the characteristics of the model. Discrete systems show changes in state at different time points. Discrete system simulation is becoming more popular because of its easier modelling constructs, and is mostly found in operations research and management science. Discrete systems simulation models consist of physical models and logic models. The physical model is a physical replica of a real system, which is built for virtualization so that it is easy to read and clearly told. All function models are logical models, and the sequence is a key part of the system because it is needed to simulate real situations [15].

Discrete systems can be treated directly within the framework of dynamic system theory, but continuous systems first require a reduction process that depends on variations or fluctuations in work at the macroscopic scale. Discrete system models are designed to carry out operations represented mathematically by the difference equation [16].

2.3. Simulation definitions
System simulation can be defined as an imitation of real processes and events in the context of research, investigation, trial and testing which are focused on certain activities or operations with the aim of knowing the characteristics, circumstances, and other matters relating to the existence and state of real activities and events. Imitation in simulation does not produce the same system or object and does not aim to duplicate the system or object. Imitation in simulation aims to present a real system in a virtual form through the use of imitation components and structures [17].

Simulation models in the form of computer programs illustrate the mechanism of the system under consideration. Coding a model can be done in many ways, including by compiling programs that only focus on system components, system structure, relationships between components, and system behavior being modelled. With reference to the dynamic simulation model, the system status changes at each time step, where the model updates the system status, and calculates events at the next time step. Simulation, simply, is the implementation of a model that requires further definition of the initial conditions of the system under consideration, and the parameter values specified [18, 19].

The application of simulation involves specific steps so that the simulation study is successful. Regardless of the type of problem and the purpose of the study, the process carried out by the simulation remains constant. The following briefly explains the basic steps in the simulation process [14, 20]:

1) **Problem formulation.** Research must begin with a statement of the problem, and the analyst must ensure that the problem being explained is clearly understood. This initial step involves determining the research objectives and what needs to be solved. Next, the problem is defined through objective observation of the process to be studied.

2) **Setting goals and overall project plan.** Goal setting indicates the question must be answered. The overall project plan must include a statement of the alternatives being considered as well as the methods used to evaluate the effectiveness of these alternatives. In this case, scheduling is necessary to determine whether sufficient time and resources are available to be completed.

3) **Model conceptualization.** Conceptualization aims to understand how the actual system behaves and determine the basic requirements of the model needed in developing the right model. Creating a flowchart of how the system operates facilitates an understanding of what variables are involved and how these variables interact. Development of a system model is needed to abstract important features of a problem, and select and modify the results of basic assumptions.

4) **Data collection.** An objective study determines the type of data to be collected, including data that will be used to validate the simulation model. After formulating the model, the type of data to be collected is determined. Data needs to be adjusted according to theoretical distribution.
5) **Model translation.** Real world systems generally produce models that require data processing and information storage, so system models must be designed, translated and entered in a format that can be recognized by computers. In this case the model is translated into a programming language.

6) **Verification.** Verification is needed to ensure that the computer program prepared for the simulation will function properly. Verification to ensure that the model behaves as desired, usually requires debugging.

7) **Validation.** Validation usually requires model calibration by the iterative process of comparing the model against actual system behavior and using the difference between the two. Validation aims to ensure that there are no significant differences between the model and the real system and that the model reflects reality.

8) **Experimental design.** Alternatives that need to be simulated must be determined. Decisions must be made regarding the duration of the initialization period, the length of the simulation running, and the replication that will be made from each run.

9) **Simulation execution.** The simulation is executed by running the program as an interpretation of a model or algorithm imitating a real system. Simulations are performed using data generated or provided using reference data patterns.

10) **Documentation and reporting.** The simulation results need to be documented and reported to all stakeholders.

### 3. Results and discussion

#### 3.1. Problem formulation

The main problem faced by the company is related to determining the right amount of weekly production to meet the demand for all DCs. In this case, relatively high production will incur inventory costs, while relatively low production will lead to lost opportunities. So it is important to determine the optimal weekly production target to get the maximum profit.

#### 3.2. Data collection

For simulation purposes, the number of weekly requests for egg trays within a period of 6 months or 26 weeks ago was collected. Statistical analysis of the number of weekly requests per DC is then performed to find out the distribution patterns, as well as for the total requests of the four DCs. The number of weekly requests and the results of statistical analysis obtained are presented in the following table 1.

| No.     | DC1  | DC2  | DC3  | DC4  | All DCs |
|---------|------|------|------|------|---------|
| Average | 2.840| 2.616| 2.617| 2.492| 10.566  |
| Maximum | 3264 | 3405 | 3085 | 3021 | 12004   |
| Minimum | 2502 | 2026 | 2116 | 2116 | 9277    |
| Pattern | Gen Pareto | Gen Extreme | Gen Extreme | Uniform | Beta* |

*Beta Pattern with parameter: $\alpha_1 = 0.54738$, $\alpha_2 = 0.57427$, $a = 9.277$, $b = 12.004$

The most appropriate distribution pattern for the total number of weekly requests is the Beta pattern. This pattern is used as a reference in the process of generating imitation data for the total number of weekly requests in the simulation. The generation of imitation data for the number of requests per week is done for 26 weeks in one period. Before being used, this imitation data is analyzed to ensure that its distribution pattern is the same as the historical data distribution pattern.

#### 3.3. Simulation model

The simulation model to determine the optimal production target is presented in the form of a block diagram in figure 1. In this model a request fulfillment operation is carried out per week. The simulation
operation is dynamic, where previous stock (if available) is used to meet current demand, and the excess current stock is stored as stock for the following week.

\[ P_i : \text{Production at period } i \]
\[ S_i : \text{Stock at period } i \]
\[ D_i : \text{Delivery at period } i \]

**Figure 1.** Dynamic model of weekly stock determination.

The model of determining the shortage or excess supply per week is done by using the algorithm presented in figure 2. The available supply is obtained from the summation of the current production in one week with the available stock from the previous week. If the available supply is greater than the current demand, the excess will be saved for the following week. But if supply is less than demand, the shortage is considered a lost opportunity.

\[ D > (P+S) \Rightarrow \text{Shortage (Opportunity Loss)} \]
\[ D < (P+S) \Rightarrow \text{Excess (Holding Cost)} \]

**Figure 2.** Model of determining shortages and excess stocks

### 3.4. Verification

Verification is done by checking whether the algorithm designed will show the same conditions and consequences as happened in a real production system. In a real system, large quantities of production can successfully meet the demand for all DCs, but have the potential to cause excess stock. Conversely, low production capacity will result in certain DC requests not being fully supplied, with the effect of losing opportunities for companies to make a profit.

The same effect is also shown by the algorithm, where excess stock occurs if weekly production is relatively high, and supply shortages to meet demand occurs if weekly production is relatively low. This similarity shows that the algorithm is valid in representing real system operations.

### 3.5. Experiments

Experiments were carried out to determine the total gain obtained at different weekly production levels (number of egg tray packages). The simulation is run at 9 weekly production levels, i.e. 10,000 packages (PL1), 10500 packages (PL2), 11000 packages (PL3), 11500 packages (PL4), 12000 packages (PL5),
12500 packages (PL6) 13000 packages (PL7), 13500 packages (PL8), and 14000 packages (PL9) per week. Experiments for each level of production were carried out within 26 weeks. Experiments for each level of production were repeated 10 times, and the average total gain obtained was recorded as a result of 1 replication simulation. The total gain is calculated using the formula:

$$\text{Total Gain} = \text{Total Expected Gross Profit} - \text{Total Opportunity Loss} - \text{Total Holding Cost} \quad (1)$$

For example, calculation of total gain in 26 weeks at the level of 11000 packages egg tray per week is:

$$\text{Total Gain} = \text{Total Expected Gross Profit} - \text{Total Opportunity Loss} - \text{Total Holding Cost} = \text{IDR} \ 2.462.789.700 - \text{IDR} \ 124.830.900 - \text{IDR} \ 6.927.850$$

Total Gain = IDR 2.331.030.950

Where:

Gross Profit: IDR 9000 per packages and Holding Cost: IDR 50 per packages per week

3.6. Validation

Validation is done to ensure that the average of the simulation results with the number of replications carried out is valid to represent the actual system. For this purpose, simulations for each level of weekly production are carried out with 12 replications. The recapitulation of simulation results and statistical analysis of total profits are presented in table 2 below.

**Table 2.** Average total gain in 26 weeks (x IDR 1000000).

| Replication | PL1  | PL2  | PL3  | PL4  | PL5  | PL6  | PL7  | PL8  | PL9  |
|-------------|------|------|------|------|------|------|------|------|------|
| 1           | 10000| 10500| 11000| 11500| 12000| 12500| 13000| 13500| 14000|
| 2           | 2158.532 | 2253.168 | 2354.297 | 2464.134 | 2453.352 | 2462.693 | 2516.297 | 2557.613 | 2412.175 |
| 3           | 2102.157 | 2230.028 | 2348.566 | 2454.214 | 2463.121 | 2554.497 | 2426.354 | 2479.793 | 2457.835 |
| 4           | 2094.378 | 2255.144 | 2380.278 | 2437.194 | 2503.141 | 2467.858 | 2486.108 | 2385.052 | 2455.615 |
| 5           | 2099.271 | 2243.746 | 2370.523 | 2423.293 | 2565.950 | 2491.992 | 2512.296 | 2437.464 | 2465.810 |
| 6           | 2220.904 | 2245.157 | 2400.074 | 2428.562 | 2461.721 | 2456.570 | 2500.048 | 2433.414 | 2455.150 |
| 7           | 2094.531 | 2267.784 | 2385.352 | 2425.107 | 2445.175 | 2551.991 | 2565.057 | 2451.042 | 2461.362 |
| 8           | 2144.913 | 2328.488 | 2344.608 | 2497.934 | 2523.442 | 2481.607 | 2453.343 | 2480.391 | 2417.985 |
| 9           | 2196.370 | 2249.557 | 2333.165 | 2431.423 | 2505.292 | 2475.132 | 2435.523 | 2492.468 | 2465.303 |
| 10          | 2100.943 | 2271.143 | 2357.015 | 2485.812 | 2483.543 | 2520.511 | 2514.303 | 2510.755 | 2444.493 |
| 11          | 2165.332 | 2264.988 | 2352.924 | 2470.104 | 2531.184 | 2499.776 | 2405.765 | 2463.974 | 2424.782 |
| 12          | 2143.520 | 2239.398 | 2340.051 | 2402.275 | 2498.365 | 2622.012 | 2523.612 | 2434.892 | 2423.377 |

| TG | 25668.760 | 27018.418 | 28326.356 | 29378.954 | 29949.769 | 30072.807 | 29870.187 | 29558.249 | 29240.108 |
| AVG | 2139.063 | 2251.535 | 2360.530 | 2488.246 | 2495.814 | 2506.067 | 2489.182 | 2463.187 | 2436.676 |
| SD | 42.170 | 12.789 | 19.874 | 29.050 | 35.954 | 48.142 | 48.457 | 44.945 | 31.948 |
| hw | 26.794 | 8.126 | 12.627 | 18.458 | 22.844 | 30.588 | 30.789 | 28.557 | 20.299 |
| UCL | 2165.857 | 2259.661 | 2373.157 | 2466.704 | 2518.658 | 2536.656 | 2519.971 | 2491.745 | 2456.975 |
| LCL | 2112.269 | 2243.409 | 2347.902 | 2429.788 | 2472.970 | 2475.479 | 2458.394 | 2434.630 | 2416.377 |

Based on the results of the statistical analysis presented in table 2 above, the number of replication simulations n = 12 is greater than the minimum number of replications needed, where for the level of confidence $\alpha = 0.05$ and degrees of freedom $d = n - 1 = 11$, the minimum number of replications needed
is n' = 9.52. This means that the minimum amount of replication has been met, so that the total gain obtained with 12 replications for each level of weekly production can be accepted as a valid value.

3.7. Simulation results

The total gain presented in table 2 are calculated using three elements: total expected profit based on demand, opportunity loss, and holding costs for excess stock. The value of total opportunity loss (OL) and total holding cost (HC) at 9 levels of weekly production is presented graphically in figure 3.

![Figure 3. Total opportunity loss and total holding cost in 26 weeks](image)

The level of production with a higher average total gain presented in table 4 varies between 12000 and 13000 packages per week. The highest average total gain in 26 weeks is IDR 2506 million at a production level of 12500 packages per week, as shown in Figure 4. At lower and higher levels of 12500 packages per week, the average total profit is lower, so the optimal weekly production is at level 12500 packages/week. In accordance with regulations six working days per week, the optimal daily production target for egg trays is 12500/6 = 2083 packages, ideally rounded to 2100 packages per day.

![Figure 4. Average total gain in 26 weeks.](image)

4. Conclusion

The results of this study indicate that the total gain per week can be predicted by using simulations. The use of discrete system simulation with dynamic models at PT. MNO shows that the average total gain
depends on the adequacy of egg tray production per week to meet demand. Experiments that have been carried out show that average total gain differ at 9 levels of weekly production. Validated simulation results are obtained with 12 replications and 10 simulation iterations per each replication. Based on total gain at each weekly production level, optimal weekly egg tray production with the highest total gain is obtained at the level of 12500 packages per week.

Finally, the results of this study show that the use of a discrete system simulation is appropriate and good in determining the optimal amount of weekly production.

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