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by Surya Saputra

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Design Of Dynamic System Simulation Model Of Trash Bin Production Process at Harapan Mulya Putri Company

Surya Saputra[a], Ratna Mira Yojana[a*], Pudji Astuti[a]

[a] Faculty of Industrial Technology, Universitas Trisakti, Jln. Kyai Tapa No. 1 Jakarta 11440.
surya063001900013@std.trisakti.ac.id, ratna.mira@trisakti.ac.id, pudji@trisakti.ac.id

ABSTRACT

Harapan Mulya Putri is a manufacturing company established in 2010. This company produces equipment for cleaning or cleaning tools, hotel equipment, restaurant equipment, household equipment, and traffic signs. Problems encountered by Harapan Mulya Putri company that the number of stainless steel trash backorders will reach 28% in 3 months. This study aims to reduce the number of back orders in the production process of stainless steel trash bins. Reducing the number of back orders is done by designing a simulation model of stainless steel trash bin production. The method used is a dynamic system simulation. Three scenarios are used to maximize the fulfillment of consumer demand. The first scenario is a policy of adding raw materials suppliers send, such as 150 units of stainless steel plates. The simulation results for the first scenario resulted in a 75% decrease in back orders. The second scenario is ordering based on the bill of material grouping to optimize raw material utilization. The simulation results of the second scenario reduced back orders by 56.25%. The third policy scenario is combined with the first and second scenarios. The results of the third simulation show that back orders have decreased by 87.5%. Thus, the selected scenario is the third scenario.

Keywords:

System Dynamic, Simulation Model, Stock Flow Diagram, Back Order

Introduction

Harapan Mulya Putri Company is a manufacturing company that was established in 2010. This Company is engaged in the manufacturing, producing, and distributing cleaning equipment, one of which is stainless steel trash bins. This Company implements the Make Order production type, which means that the Company will produce goods after the customer pays a Down Payment. Harapan Mulya Putri Company produces according to the specifications requested by the customer or can also be customized. The production process is adjusted to the requirements and schedules desired by consumers and the availability of time owned by the Company. Table 1 shows that the demand for stainless steel trash cans is experiencing winter, with a production failure of 28%. This value is considered high for the Company and causes losses. Failure to achieve this production hampers the following production process, expanding the production target. In addition, this also results in the Company paying a fine due to late delivery (penalty).

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Table 1. Historical data on the production of PT. Harapan Mulya Putri stainless steel trash bins

Number	order date	Demand (unit)	Request Delivery date	Production Results (unit)	Request not reached (unit)	Delivery date	Result
1	5/1/2022	180	11/1/2022	180	0	11/1/2022	achieved
2	10/1/2022	30	13/1/2022	30	0	13/1/2022	achieved
3	12/1/2022	80	14/1/2022	80	0	14/1/2022	achieved
4	13/1/2022	85	18/1/2022	85	0	18/1/2022	achieved
5	17/1/2022	200	1/2/2022	160	40	2/2/2022	not achieved
6	19/1/2022	175	26/1/2022	120	55	28/1/2022	not achieved
7	24/1/2022	35	27/1/2022	35	0	27/1/2022	achieved
8	27/1/2022	150	28/2/2022	120	30	1/3/2022	not achieved
9	31/1/2022	220	8/2/2022	120	100	12/2/2022	not achieved
10	2/2/2022	50	5/2/2022	50	0	5/2/2022	achieved
11	3/2/2022	70	7/2/2022	70	0	7/2/2022	achieved
12	3/2/2022	20	5/2/2022	20	0	5/2/2022	achieved
13	7/2/2022	200	14/2/2022	150	50	16/2/2022	not achieved
14	14/2/2022	80	17/2/2022	80	0	17/2/2022	achieved
15	18/2/2022	180	26/2/2022	120	60	28/2/2022	not achieved
16	21/2/2022	150	21/3/2022	90	0	21/3/2022	achieved
17	23/2/2022	100	25/2/2022	100	0	25/2/2022	achieved
18	25/2/2022	240	11/3/2022	160	80	14/3/2022	not achieved
19	26/2/2022	60	29/2/2022	60	0	29/2/2022	achieved
20	1/3/2022	30	4/3/2022	30	0	4/3/2022	achieved
21	5/3/2022	105	9/3/2022	105	0	9/3/2022	achieved
22	5/3/2022	70	9/3/2022	70	0	9/3/2022	achieved
23	8/3/2022	175	15/3/2022	150	25	17/3/2022	not achieved
24	9/3/2022	50	14/3/2022	50	0	14/3/2022	achieved
25	10/3/2022	65	14/3/2022	65	0	14/3/2022	achieved
26	12/3/2022	180	12/4/2022	150	30	16/4/2022	not achieved
27	13/3/2022	25	16/3/2022	25	0	16/3/2022	achieved
28	18/3/2022	85	22/3/2022	60	25	24/3/2022	not achieved
29	18/3/2022	15	21/3/2022	15	0	21/3/2022	achieved
30	26/3/2022	30	29/3/2022	30	0	29/3/2022	achieved
31	30/3/2022	90	2/4/2022	90	0	2/4/2022	achieved
32	4/4/2022	35	7/4/2022	35	0	7/4/2022	achieved
33	8/4/2022	180	14/4/2022	180	0	14/4/2022	achieved
34	12/4/2022	80	18/4/2022	80	0	18/4/2022	achieved
35	17/4/2022	15	20/4/2022	15	0	20/4/2022	achieved
36	23/4/2022	160	23/5/2022	160	0	23/5/2022	achieved
37	4/5/2022	65	7/5/2022	65	0	7/5/2022	achieved
38	8/5/2022	120	14/5/2022	120	0	14/5/2022	achieved
39	12/5/2022	90	18/5/2022	90	0	18/5/2022	achieved
40	17/5/2022	120	31/5/2022	120	0	31/5/2022	achieved
41	23/5/2022	150	30/5/2022	120	30	3/6/2022	not achieved
42	27/5/2022	30	30/5/2022	30	0	30/5/2022	achieved
43	27/5/2022	20	30/5/2022	20	0	30/5/2022	achieved
44	30/5/2022	150	8/6/2022	130	20	10/6/2022	not achieved

45	1/6/2022	180	18/6/2022	150	30	1/7/2022	not achieved
46	1/6/2022	20	3/6/2022	20	0	3/6/2022	achieved
47	5/6/2022	25	7/6/2022	25	0	7/6/2022	achieved
48	7/6/2022	80	11/6/2022	80	0	11/6/2022	achieved
49	11/6/2022	160	15/6/2022	125	35	16/6/2022	not achieved
50	11/6/2022	55	15/6/2022	55	0	15/6/2022	achieved
51	18/6/2022	70	20/6/2022	70	0	20/6/2022	achieved
52	19/6/2022	15	21/6/2022	15	0	21/6/2022	achieved
53	19/6/2022	200	26/6/2022	130	70	28/6/2022	not achieved
54	21/6/2022	135	26/6/2022	96	39	27/6/2022	not achieved
55	25/6/2022	20	27/6/2022	20	0	27/6/2022	achieved
56	26/6/2022	100	29/6/2022	100	0	30/6/2022	achieved
57	30/6/2022	40	4/6/2022	40	0	4/6/2022	achieved

The late delivery is then called a backorder, which is some goods that have been promised to consumers but have yet to be fulfilled because the Company needs inventory [1], [2]. The number of backorders will reduce consumer confidence. Even so, backorders can be divided into two types: total backorder and partial backorder. If consumers are willing to wait for a late product, it is called a partial backorder; conversely, if consumers do not accept the delay, it is called a full backorder. Several methods have been developed to reduce the number of backorders. Zhang et al. (2012) designed inventory using a hybrid genetic algorithm (HGA) method that combines heuristic search techniques, balances inventory costs with setup costs, and considers the number of backorders[3]. Dey et al. (2021) created the concept of marginal backorder and developed an intelligent manufacturing system by considering stochastic demand and flexible production levels [4]. According to Pillai and Pamulety, 2013 backorders can cause a bullwhip effect, a phenomenon in supply chain management where mobilizing demand at the consumer level causes more significant distortion along the supply chain, from retailers to distributors to manufacturers [5]. This results in an alignment between actual demand and projected demand so that each stage in the supply chain orders more inventory than needed, creating waves of increasing and decreasing orders greater than increasing initial demand.

System Dynamics is a mathematical technique used in multistage decision-making, one of which is for optimizing production planning [6]. Since entering the digital era, the system has become more dynamic. The advantage of the dynamic system method is its ability to consider movements between system elements so that it is more representative of natural conditions [7]. The method used in this research is dynamic systems. Dynamic systems are a methodology and mathematical modeling technique to frame, understand, and discuss complex problems [8], [9]. This research aims to design a dynamic system model in the trash can production process and to provide a proposed scenario for improving the production system to meet consumer demand and reduce the number of backorders.

Methods

The study began with a preliminary study, namely conducting a survey and interview with the manager of Harapan Mulya Putri Company, so that the problems and objectives of the study were obtained. The method used in this study is a dynamic system. Figure 1 is the methodology used in this study. The dynamic system method was chosen because it can describe the movement of a system with changes in time [10], [11]. The dynamic system method focuses on policy-making and observing the system's behavior resulting from the policy's implementation, which can be modeled dynamically [12], [13]. The main focus of the dynamic system methodology is to understand a system so that problem-solving steps provide feedback on the system's movement [14], [15]. The steps in the dynamic system process described by Jay Forrester:

1) Describe the system
   The system description is carried out through survey activities, deep interviews, historical companies, and literature studies to obtain the correct problem statement.
2) Convert descriptions to level and rate equations.
   After creating the problem statement, a conceptual modeling design of the stainless steel trash bins production system was carried out.
3) Model simulation
   The conceptual model designed was transformed into a simulation model using Vensim software.
4) Design alternative policies and structures.
   In this research, three scenarios were created, the best scenario selection indicator being the scenario with the smallest number of backorders.
5) Educate and debate
   The lowest number of backorders in this research was obtained in the third scenario by combining the first and third scenarios.
6) Implementation of policies and structures.
   The third scenario can reduce the number of backorders by 87.5%.

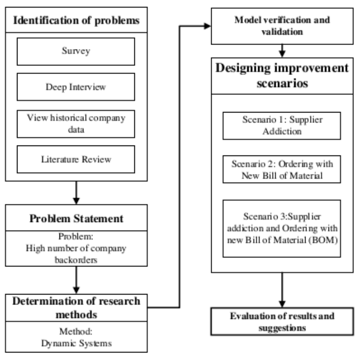

Figure 1. Research methods

The Dynamic System Method uses Stock and Flow Diagrams to represent the structure entirely so that it can be developed into a mathematical model formulation for simulation. This diagram has the highest level of accuracy. In this diagram, you can distinguish between physical and information sub-systems and classify variables and functions into their respective types [14], [16].

Verification and validation are carried out in research to ensure the model created is by the research objectives. Verification is a step to ensure that the conceptual model is based on a computational model. Meanwhile, validation ensures the computational model meets the desired objectives [17], [18]. A model can be said to be good if the error or deviation from the simulation results regarding a phenomenon or process being imitated is small. A computational model's error value is considered small if it is less than 10% [19]. Furthermore, the simulation results obtained will be used to understand the behavior of future symptoms or processes [20].

This modeling is validated by comparing the model's behavior with the natural system. (quantitative behavior pattern comparison) with the MAPE test. MAPE, or mean absolute percentage error, is one of the relative measures involving percentage error. This test can determine the suitability of forecast data with actual data [21].

$$MAPE = \frac{1}{n}\sum \frac{|x_m - x_d|}{x_d} \times 100\% \quad (1)$$

Information :

x_m = Result Simulation Data
x_d = Actual Data
n = Periodic

The analysis results are obtained after getting the suitable system model to design improvement scenarios. Scenario repair designed by objective research, i.e., reduces the number of backorders. Three scenarios were applied to the research: scenario addition of suppliers, scenarios customized ordering with bill of materials, and scenarios combined. Modeling results of all three scenarios were observed. Then, the recommendation scenario was chosen best.

Results and Discussion

The object of this research is a stainless steel trash can produced by Mulya Harapan Putri Company. After determining the research objectives, the initial research stage identifies stakeholders and stakeholder needs. Stakeholders are parties directly related to achieving research objectives, namely maximizing the fulfillment of demand to meet the needs of Company consumers. Mulya Harapan Putri. Identifying needs shows each stakeholder's needs and the goals to be achieved [22]. After that, variable identification was carried out using a diagram system. A system diagram is a diagram that can explain in detail the relationship between conceptual model input, causal loop diagram, output, stakeholders, the purpose of creating the model, and alternative strategies[23], [24]. Causal loop diagram can describe relationships and relationships between variables[25], [26]. Figure 2 shows a system diagram.

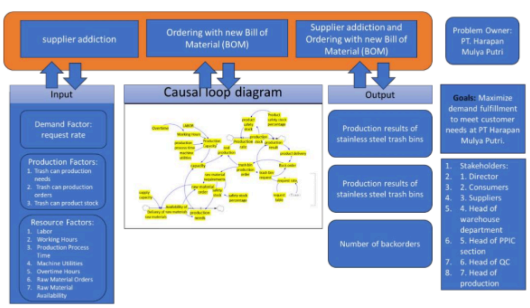

Figure 2. System Diagram

Figure 2 is a system diagram of Mulya Harapan Putri Company, which aims to maximize demand to meet consumer needs. This diagram was designed based on the results of in-depth interviews with the production director of Harapan Mulya Putri Company as well as literature studies that have been carried out. In the system diagram, input factors are divided into three parts: demand factors, production factors, and resource factors. Input to the diagram system is obtained based on the variable identification stage. After determining the input to the system, a causal loop diagram can be created to describe the relationship between variables according to the actual situation. The output of the diagram can be determined based on the causal loop diagram. The output obtained in the diagram system is the number of production results for stainless steel trash cans, the availability of raw materials, and the number of backorders. Based on the causal loop diagram, a stock-flow diagram is created. The stock-flow diagram illustrates the relationship between related variables in the stainless steel trash can production process [27], [28]. The relationships between variables are connected with model formulations created with functions available in the Vensim software. Figure 3 is a stock-flow diagram for producing stainless steel trash cans.

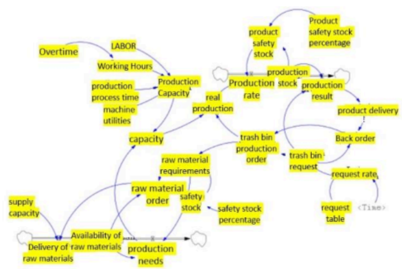

Figure 3. Stock Flow Diagram

Based on the stock flow diagram in Figure 3, production results increase based on the production rate and stock of stainless steel trash can products. Production rate is influenced by actual production, which is influenced by production orders for trash cans and P&BB capacity (production and raw materials). P&BB capacity is influenced by production capacity based on the number of workers, process time, machine utility, working hours, and overtime hours. These five factors determine the production capacity that will influence the maximum number of products a company can produce. If the production capacity is small, it will affect the production rate so that the product stock will increase. The production results will follow what is desired because they are influenced by production stock and demand. Then, the production results will continue to send TSS products and cause backorders for trash cans stainless steel. Apart from capacity, the availability of raw materials can also affect backorders. The availability of raw materials will increase if there is a delivery of raw materials, which will decrease production needs. Orders for producing stainless steel trash cans influence the availability of raw materials. The higher the availability of raw materials, the greater the need to produce stainless steel trash can products.

Model formulation by inputting variables into the Vensim software and entering mathematical equations and units for each variable into the stock flow diagram. The model formulation and units are presented in tabular form in detail, as shown in Table 2.

Table 2. Model Formulation Unit

No	Variable	Model Formulation	Unit
1	Availability of Raw Materials	Delivery of Raw Materials-Production Needs	Units
2	Stock of Trash Bins Products	Production Rate-Production Yield	Units/Day
3	Request Table	Consumer Demand Data (Actual)	Units
4	Overtime Hours	4*2	Hours/Day
5	Machine Utilities	0.49	Dmnl
6	Production Process Time	0.931	Hours/Units
7	Working hours	16	Hours/Day
8	Labor	20	People/Day
9	Overtime	8*0.6	Hours/Day
10	Supply Capacity	150	Units
11	Percent Safety Stock	100* Percent Safety Stock Products	Units/Day
12	Percent Product Safety Stock	0.1	Units/Day
13	Production Capacity	(Working Hours*Labor*Machine Utility/Production Process Time)	Units/Day
14	Real Production	MIN("P&BB Capacity",Trash Bins Production Order)	Units/Day
15	Raw Material Requirements	Order Production of Trash Bins + Safety Stock	Units/Day
16	Order Raw Materials	MIN (Raw Material Requirement, Raw Material Availability)	Units/Day
17	Raw Material Delivery	MIN (Order Raw Materials, Supply Capacity)	Units/Day
18	Safety Stock	100*Percent Safety Stock	Units
19	Trash Bins Production Order	Trash Bins Request + Back Order	Units/Day
20	Product Delivery	Production Results	Units/Day
21	Trash Bins Request	Demand Rate	Units/Day
22	Back Orders	Trash Bins Request-Product Delivery	Units/Day
23	Demand Rate	Request Table(Time)	Units/Day
24	Production Results	MIN (Trash Bins Request, Product Stock)	Units/Day
25	Product Needs	MIN (Availability of Raw Materials, Requirement of Raw Materials)	Units/Day
26	Safety Stock of Products	TSS Product Stock*Percent Product Safety Stock	Units/Day
27	Production Rate	Real production + Safety Stock of TSS Products	Units/Day
28	P&BB capacity	MIN (Production Capacity, TSS Production Requirements)	Units/Day
29	Time	-	-

The next stage is to verify the model to ensure that the conceptual model has designed the model. The model can be verified by checking it using Vensim software. In the Vensim software, menu Model and then select Check Model[29]. After that, the results can check whether there are errors in the model that have been designed in the form of formulation errors or errors in the model structure. Figure 4 shows the verified model.

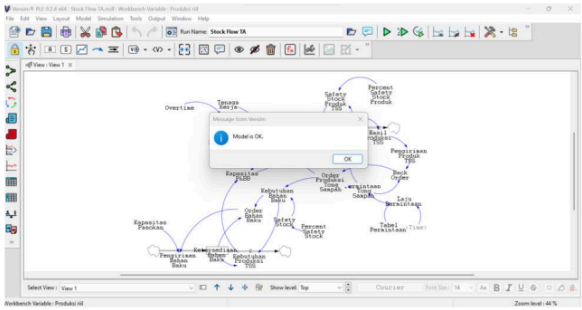

Figure 4 . Model Verification

After verifying the model, the next stage is model validation. This validation stage requires a statistical examination to compare accurate system and simulation data in the Vensim software. In this research, one of the data that we want to know and use for validation is production data. Validation calculations use the MAPE method to calculate the percentage of error or deviation in the simulation model [30]. The results of the MAPE calculation for production results is 4.25%, so the model is declared feasible because according to the MAPE test criteria, if the model percentage results have a value below 10%, it is declared an exact and accurate model [31].

In this research, apart from production data, backorder data is used. Validation checks were also carried out on the backorder data using the MAPE method to calculate the percentage of error or deviation in the simulation model. The simulation results obtained a MAPE value of 9.67%, so the model was declared feasible because, according to the MAPE test criteria, if the percentage model results had a value below 10%, it was declared an exact and accurate model[32]. Based on the analysis of the results, one of the dominant factors that can reduce back orders is increasing the availability of raw materials [33]. Availability of raw materials can be increased by adding suppliers. At the start of the simulation, the number of raw material suppliers was one supplier with a capacity of 150 units of stainless plate. This policy scenario adds one supplier with 150 stainless plate unit capacity. Figure 5 shows the results of the backorder simulation after the resource adjustment policy scenario was carried out by adding suppliers.

Figure 5. Resource adjustment back order graph-scenario 1

Based on the simulation results, back orders experienced a very significant decline. Figure 5 shows that back orders in period 19 and onwards are worth 0 for resource adjustments with the addition of suppliers with a capacity of 150 units of stainless steel plates. The results for adjusting resources with the addition of suppliers are pretty effective in reducing backorders. Based on the formulation of the problem to minimize the disposal of stainless steel plate waste, the results will be analyzed to reduce the occurrence of back orders.

The second scenario is ordering based on the bill of materials (BOM). This scenario was chosen because adjusting orders using BOM can save the raw materials needed and speed up production [34]. Orders based on BOM are simulated by separating the availability of raw materials that were previously directly for 1 unit of product. In contrast, scenario two is divided into three parts: stainless steel trash can base, stainless steel trash can body and stainless steel trash can lid. Figure 6 shows the simulation model for scenario two by separating the availability of raw materials into three parts.

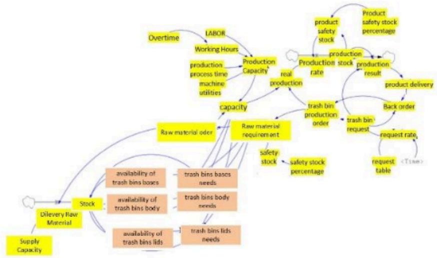

Figure 6. Stock and Flow Diagram Ordering Based on BOM

This model, is adjusted to the existing needs; Figure 6 shows the separation of stock flow into three parts, namely the lid, base, and body of the stainless steel trash can. Ordering Based on BOM is to maximize the fulfillment of consumer demand and maximize the available raw materials. The following graph in Figure 7 shows the results of the backorder simulation after the BOM-based ordering policy scenario was carried out. The model is run after creating the Stock Flow Diagram, and the number of back orders in the system is observed. Figure 7 shows the results of the back order simulation after carrying out the Order Based on BOM policy scenario.

Figure 7. Resource adjustment back order graph-scenario 2

Based on the simulation results, back orders experienced a significant decrease. Figure 7 shows that back orders on the graph have decreased significantly from the backorder results before the simulation model adjustment. Based on BOM simulation, the results for Ordering are pretty effective in reducing backorders. The combined policy scenario is a scenario that combines resource adjustments and Ordering Based on BOM simulation. This scenario uses the addition of suppliers with a capacity of 150 units of stainless steel plates, as in scenario one. Figure 8 shows the results of the backorder simulation after the combined policy scenario was carried out.

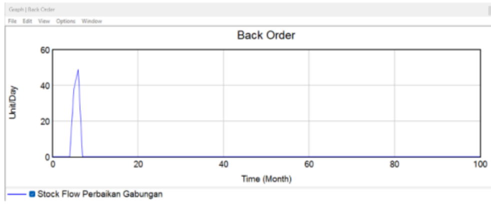

Figure 8. Resource adjustment backorder graph-scenario 3

Based on the simulation results, backorders have decreased significantly. Figure 8 shows that back orders on the graph have reduced considerably from the backorder results before resource adjustments and simulation model adjustments. The backorder results from combining these scenarios; back orders end in the 6th period, so the results for Ordering Based on BOM simulation are very effective in reducing back orders at Harapan Mulya Putri Company. Based on the explanation in the previous sub-chapter, it can be concluded that the resource adjustment policy scenario, namely adding suppliers, has a percentage decrease in back orders of 75%. The Ordering Based on BOM policy scenario has a percentage decrease in back orders of 56.25%. The combined policy scenario has the same value: a reduction of 87.5%. From the analysis of all scenarios, there are no back orders in the future. Based on the percentage decrease in back orders for all scenarios, from the three policy scenarios created, all showed significant results in reducing backorders. However, if considered based on the existing results, the combined scenario between resource adjustments, namely the addition of suppliers with a capacity of 150 units of stainless steel plates with Ordering Based on BOM simulation, is very feasible to use because, in addition to reducing back orders, it can also maximize existing raw materials.

As a result of implementing the third scenario, the company can reduce the value of back orders by up to 87.5% to meet consumer demand in the future. This is due to efficiency in the use of raw materials. In addition, implementing the third scenario will increase the company's profits because the company no longer needs to pay fines due to late deliveries.

Conclusion

In this research, a design was carried out using a dynamic system method to reduce the number of backorders for Harapan Mulya Company's stainless steel waste production. A dynamic system was chosen because it can solve complex problems and provide dynamic data. Designing a dynamic system model starts from designing the system diagram to deciding on selected scenarios with the lowest number of backorders. A validation test carried out using the MAPE (Mean Absolute Percentage Error) shows that the data results are feasible and by the system real because the results of the MAPE values are compared with the data production and demand data and back orders for stainless steel trash cans less than 10% which is then declared as valid data.

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