

Materials Inventory Management to Reduce Holding Cost and Backlog (System Dynamics Approach: A Case Study)

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ABSTRACT

This study discusses the material of inventory management to produce automobiles in PT XYZ using system dynamics methodology with a case study design. The object of this study is an automobile brand, X Type 1. It is selected as the sample because this type of automobile has a highly competitive segment and a dynamic demand. Material in this sample object is divided into four groups based on the source of the material. The purpose of this study is to analyze the material inventory management in order to reduce holding costs and backlog. Reduction in the holding cost can be used for other investments or to increase the company's profits, while the backlog reduction can improve the company's competitive advantage. Simulations were carried out in two scenarios: the demand fluctuating with an upward trend and with a downward trend, in order to describe the dynamics of demand. This study found that the holding costs and backlog reduction can be achieved by changing the safety stock coverage and lead time delivery of materials. Safety stock coverage can be changed to the lowest level the company can apply, while lead-time delivery of materials depends on the conditions and trends in demand.

Keywords: Backlog, holding cost, materials inventory, system dynamics

1. Introduction

Car sales in Indonesia from 2007 to 2014 experienced a rising demand trend, which decreased in 2009 as the global financial crisis and twice in 2014 due to the policy of the government-raised subsidized fuel prices (Indonesia-investments.com, 2015). In 2015, based on Gaikindo's data, car sales in Indonesia only reached 1 million units, a decrease by 16% compared with 2013 and 2014. Nevertheless, Indonesia has good prospects in the long term because the population of high-income typically increases, and the level of car ownership in Indonesia is still relatively low, or about 4% of the total population compared with that of other countries in the ASEAN region, which reached 30% (XYZ Group, 2015).

PT XYZ¹ is one of the largest car manufacturing companies in Indonesia and produces the X² brand car. The X brand car is a multipurpose vehicle (MPV), which has a large market share in Indonesia and one of the largest sales volumes in PT XYZ, specifically sales of car X type 1 (hereinafter referred to as X1). One of the problems faced by PT XYZ is the dynamism of

¹ Company name disguised by request of interviewees

² Product name disguised by request of interviewees

consumer demand and the market. For the production plan, Y Sales & Operations (YSO³), as primary dealers from the same group as XYZ, will arrange the plan while considering several factors, which is the cars' inventory ratio that still exists in the branch or dealer, the target market from the board of directors, macroeconomic and real market conditions, and production capacity. This initial production plan, called "planned order," will be implemented over the next few months. However, one month prior to manufacture, YSO will adjust production plans by looking at all the various factors and latest cars sales in every branch and dealer and also look at competitor strategies, such as giving high price discounts or new product launches. Adjustment of the production plan is called the "revised order." Although the revised order itself has restrictions that follow the company policy, and because XYZ purchases materials with a planned order and manufactures the car by following the revised order, material inventory management becomes more complex.

When the number of cars X1 requested in the revised order rise above the planned order and beyond the limits set by the company, the amount of actual production will fall below demand, which is called "positive backlog" (Tersine, 1994). Whereas when the number of cars X1 requested in the revised order fall under planned order, then PT XYZ will check whether the change is well within the limit. If not, then the amount of actual production will exceed the revised order, and there will be a surplus of production, which is called a negative backlog (Marca, et al., 2010). Positive and negative backlog will affect production plans in the next month, which the positive backlog will add to the production plan, and the negative backlog will reduce it. The impact of the positive backlog is the potential loss of sales, which, if it occurs continuously and in the long run, will have a negative effect on the company's reputation and revenues, which is not optimal, while the impact of the negative backlog is excess inventory at each dealership and branch; thus, their holding costs become high. In the long run, this may affect the sustainability of their businesses, which also would have an impact on PT XYZ. The ideal state is to keep the backlog value low or near zero and either as positive or negative backlog (Marca, et al., 2010).

Companies can minimize backlog by keeping material inventory levels to an optimal amount. With the optimal inventory levels, PT XYZ can reduce holding costs and also the value of the backlog. The holding cost is one type of inventory costs that companies spend when storing the goods in a given period (Waters, 2003). Although it is difficult to count them, and many companies are not taking them seriously, the cost is quite large, around 19%–35% (Waters, 2003) or even 25%–55% (Richardson & Helen, 1995) of the value of goods per year, depending on the type of industry, and has a significant role in the company's financial performance (Timme & Williams-Timme, 2003).

This study aims to gain a deeper and better understanding of the complexity in materials' inventory management using system dynamics modeling methodology, which was developed by Forrester (1961) and Sterman (2000). Prior studies from Janamanchi (2011) discussed forecasting and smoothing production schedules with the purpose to eliminate the bullwhip effect and formulate policy guidelines for supply chain performance. Meanwhile, the focus of this study is to analyze material inventory management to reduce holding costs and backlog by modifying certain parameters. This reduction can increase a company's profits and also improve its competitive advantage.

³ Main dealer name disguised by request of interviewees

2. Review of Literature

Inventories consist of goods and materials stored by an organization to be used at a specified time (Waters, 2003). According to Heizer and Render (2014), in general, inventory is one of a company's assets that have a high value, representing approximately 50% of the capital invested. Heizer and Render (2014) and Waters (2003) classified inventory into raw materials, work-in-process (WIP goods), finished goods, spare parts, and consumable goods. Some companies maintain a safety stock, which is extra stock to allow for uneven demand and to cover the demand while the delivery of goods from the supplier to the company, or when the current actual demand, is higher than the demand previously planned, or when the lead time of actual delivery of the goods is higher than the planned lead time. Safety stock that is owned by a company has an impact on costs, particularly the holding cost and stockout cost. The higher the safety stock held by a company the higher the holding cost will be, but it will make the stock out cost lower, too, and also vice versa.

According to Waters (2003), each stock has a correlation with costs that must be paid by the company, and its value in each company varies. According to Waters (2003), Heizer and Render (2014), and Tersine (1994), four types of inventory costs are commonly found in various companies: 1) unit cost, which is the purchase price from suppliers; 2) stockout cost, which is cost incurred when the company could not meet the demand; 3) ordering cost, which is the cost incurred every time the company makes an order; 4) holding costs, which is the cost incurred when the company stores items within a certain period. Holding costs themselves are divided into inventory noncapital carrying cost, which is comprised of several components such as warehousing costs, the rate of obsolescence, pilferage, the level of the damaged goods, insurance costs, taxes, administration, and others, along with inventory capital charge, which is related to the cost of capital.

System dynamics is a method to enhance learning in a complex system and is often simulated by a computer in order to study the dynamic complexity, understand the source of policy resistance, and design more effective policies (Sterman, 2000). System dynamics generally use two kinds of diagrams to describe the state of a modeled system: the causal loop diagram (CLD) and stock and flow diagram (SFD). According to Sterman (2000), a CLD is an important tool to represent the feedback in a system. While the SFD consists of stock, which is an accumulation of the difference between inflow and outflow of a process that creates a delay. Stock has a crucial role in that it raises dynamism in a system, which shows the characteristics of the system's state and the basis for decision-making, raises the inertia and memory of a system, including the source of delays, and leads to an increment in inflows and outflows that cause dynamic disequilibrium to a system (Mass, 1980)

Material inventory in the model of the manufacturing supply chain becomes one of the limitations in producing (Sterman, 2000). By adding the material structure in the model of a supply chain, production will only be started if the company has enough material, and the company should continue to reserve a certain amount of material to maintain the desired level of material inventory. In the inventory management model in system dynamics, backlog arises when there is a delay of receipt of the order and delivery to fulfill the order. Delay can be caused by administrative activities, customization of goods according to customer wishes, when delivering the goods with a particular mode of transportation, and others. Accordingly, a model is only a creature of a real world problem. Thus, it seems more insightful to limit the

inclusion of the external variables in the inventory model and a case of PT. XYZ as much as possible in order to simplify the model. This will facilitate the development of a robust model with enough explanatory power for the growth process. Once created, this model could be extended later by including external factors in different settings (Farouk & Saleh, 2011).

Janamanchi (2011) examined material inventory management between two parties in supply chain management: supplier and manufacturer. Supplier and manufacturer production and shipment rate are constrained by two main factors: availability of material input in the required quantity and the availability of workforce. The simulation was conducted in four scenarios—base case, random uniform, upward trend customer orders, and downward trend customer orders—with two purposes in each scenario: to minimize cumulative average cost per unit (holding cost and cost related to workforce) and unfilled orders (order that cannot be fulfilled by both parties and with assumption that they will not affect the future orders and at the same time they are not carried forward as backlog). Janamanchi only uses safety stock coverage as the decision variable and found that, when the customer orders exhibit a trend (either upward or downward), manufacturers should be more focused on eliminating unfilled orders; further, supply chain partners not only need to share information in real time but practice formulating their inventory and production planning processes in a collaborative manner to serve the supply chain customers.

3. Research Methodology

The study began with a scientific question and involves a series of detailed procedures and specific data sources; therefore, it can be classified as a formal study. The primary objective of the formal study is to test the hypothesis or to answer scientific questions posed (Cooper & Schindler, 2011). The formulation of this research is descriptive, which wants to know the structure of the materials inventory management system at PT XYZ, and causal predictive, which makes predictions about the effects of changes in the trend of consumer demand for other variables and the holding costs as well as the backlog. The study only focused on PT XYZ as a manufacturing company that has the largest automobile production capacity in Indonesia. Therefore, this study can be classified as a case study. The case study is research, which is entirely contextual to some events or circumstances and the connection between them, so it cannot be used to predict the behavior of the population (Cooper & Schindler, 2011). Bogdan and Biklen (1982) also pointed out that the case study is a detailed examination against the background of a subject or a person or document storage or one particular event.

Materials inventory management system at PT XYZ will be modeled by dividing the system into three major subsystems: materials inventory, production line and backlog, and cost under study. The three subsystems are adapted and developed from the model proposed by Janamanchi (2011) and the manufacturing supply chain by Sterman (2000). Janamanchi develop his model in his study from a model proposed by Sterman, which also was not a case study and only offered a basic understanding about materials inventory management. In this study, because it is classified as a case study and examines only one company, PT XYZ, there are adjustments according to the real condition of material inventory management in PT XYZ. We divided the materials into four groups based on the source of the material, so four constraints will need to be considered during production process. The policy regarding planned order and revised order also creates two kinds of backlog possibilities—positive and negative backlog—both of which affect the car's order and production in the next month. Because PT XYZ produces a wide

range variety of cars, it is almost impossible to trace the workforce related to produce the X1 car only; therefore, in this study our objective is only to minimize holding costs and backlog (positive and negative). We also include lead time as a decision variable in order to minimize holding costs and backlog because there is another study conducted by Wang (2012), which shows that decrement in holding cost is possible if lead time is reduced. And, due to the nature of the automotive industry, we only use two kinds of scenarios that are possible in the future: upward and downward trends of consumer demand.

Data collection methods used in this study includes in-depth interviews and literature studies. In-depth interviews were conducted with face-to-face interviews with interviewees from PT XYZ and also from the YSO. There are four interviewees: three from PT XYZ and one from YSO. This study uses a sampling non probability method because the approach has a subjective nature, the selection of samples or interviewees are based on certain criteria. The method used is purposive sampling with judgment sampling type, which includes the selection of the sample or interviewees based on the criteria established by the researchers (Cooper & Schindler, 2011). Interviewees selected are those with sufficient experience and knowledge and can access a company's latest data. Interviews were conducted in the form of semi structured interviews and open questions, which consist of a list of questions based on the study of literature prepared in advance, but it is an open question; thus, the interviewees can answer them according to their knowledge of real conditions.

Once the data are acquired and models are completely developed, both qualitative and quantitative, then prior to simulation and analysis the validation tests were conducted. According to Barlas (1994), the validation of a model is an important step in the methodology of system dynamics, which involves the process of quantitative and qualitative tests. Three types of tests include the direct structure test, structure-oriented behavior test, and behavior pattern test. In each of these tests, several methods can be used. For a direct structure test, this study uses a parameter verification test, dimensional consistency, and extreme conditions test. For the structure-oriented behavior test, in this study the method used is the boundary behavior adequacy and sensitivity tests. The behavior pattern test will be done by comparing the chart from the historical data and the result of simulation, and then perform a series of statistic tests as proposed by Sterman (2000), which is the mean absolute error (MAE), mean absolute percent error (MAPE), and mean absolute error as a fraction of the mean (MAE/mean).

4. Results and Discussion

Once the data are acquired and developed in the form of qualitative models, then the next step is to make a quantitative model that can be simulated. Quantitative models can be seen in Figure 1 and Figure 2. Material is divided into four groups based on the source of the material, that is, the multiple source part (MSP), Japan source part (JSP), local source part (LSP), and sheet material. The types of materials in MSP, JSP, and LSP are similar; they can range from the smallest, such as a door handle or even a screw to a car engine, with the differences in quality and the price of each material. Sheet material is used for making the car body. Figure 1 shows the materials inventory subsystem, particularly MSP and LSP. JSP materials have exactly the same model structure with MSP, except on the input of each parameter, likewise with the LSP and sheet material. For MSP and JSP, as a group that has a material safety stock, there are two minor loops, as shown with the loop identifier, which existed at MSP in Figure 2. The material control loop is a cycle to see material availability and make a reservation as needed, while the

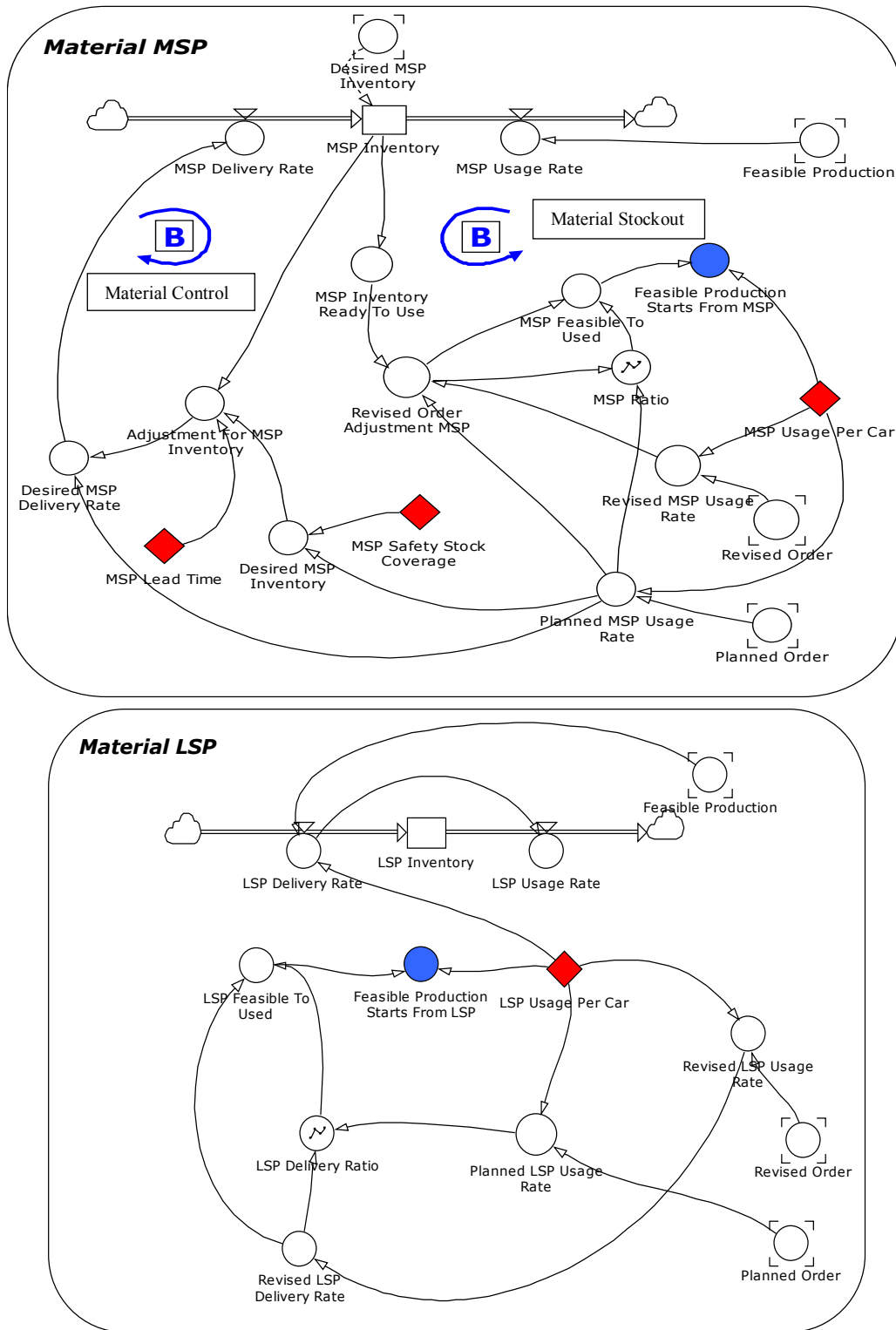


Figure 1. Material Inventory Subsystem

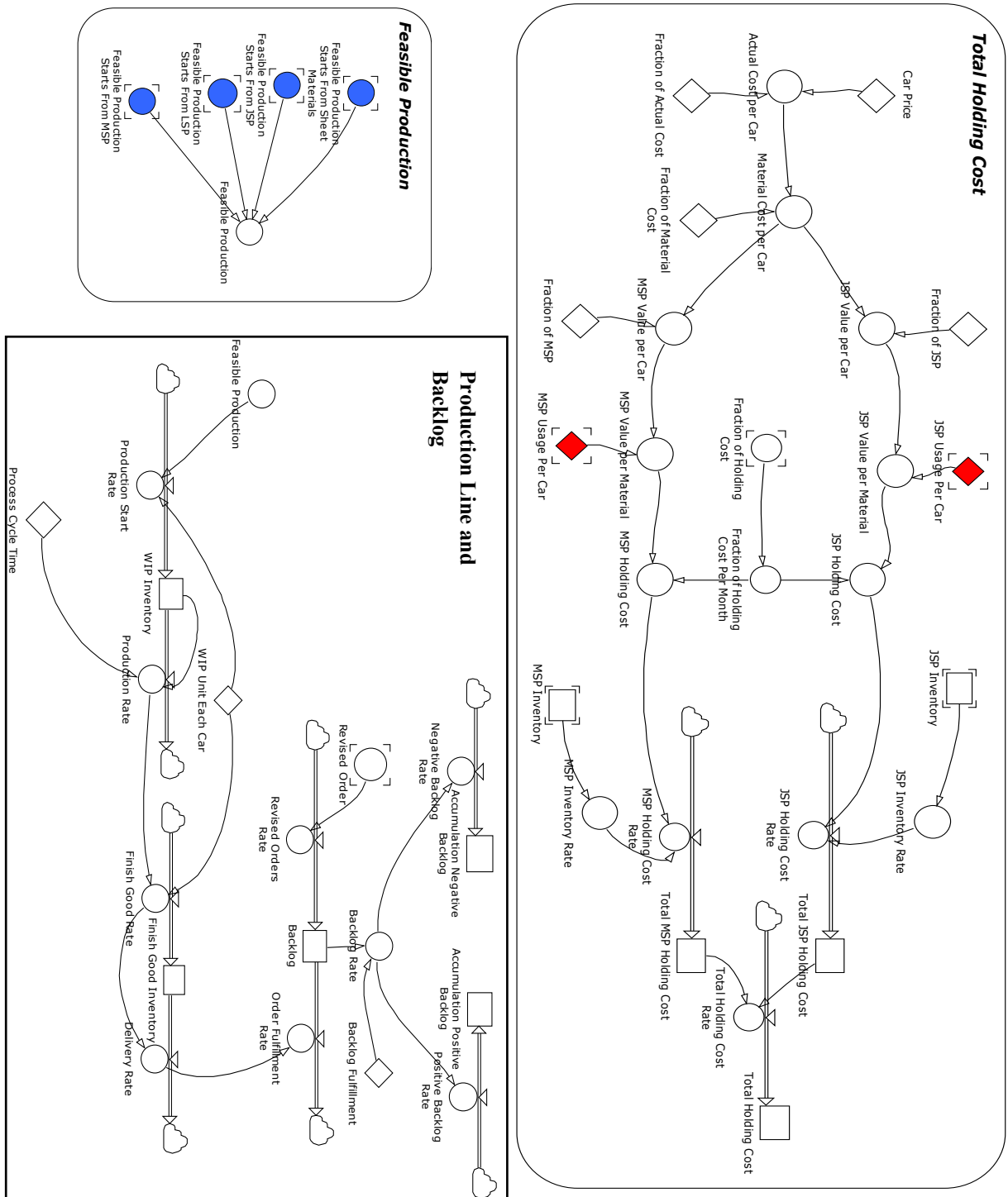


Figure 2. Production Line and Backlog and Cost under Study Subsystem

Table 1. Results from Validation Test

Test	Result
Parameter Verification	Valid
Dimensional Consistency	Valid
Extreme Condition	Valid
Boundary Adequacy	Valid
Behavior Sensitivity	Numerical Sensitivity (safety stock coverage, lead time)
Behavior Pattern	Valid, MAE = 59,77 unit, MAPE = 7%, MAE/Mean = 6%

Table 2. Decision Variable and Value

Decision Variable	Actual Value	Minimum/Maximum Value
JSP <i>Safety Stock Coverage</i>	5 day	5 – 10 day
MSP <i>Safety Stock Coverage</i>	8 day	5 – 10 day
JSP <i>Lead time</i>	1 month	0,75 – 1,25 month
MSP <i>Lead time</i>	1 month	0,75 – 1,25 month

material stockout loop is a cycle that shows the availability of materials and their use for production purposes.

After the required amount compared with the amount available in each group of material, from that four groups of material we can see how many cars are feasible to be produced, as described in the production feasible model structure in Figure 2. Then, each material will become an inflow to the production line and backlog subsystems. From these subsystems, we can determine the number of backlogs by comparing the number of actual cars that can be produced and delivered (delivery rate) with the desired from YSO (revised order). Holding costs are calculated by first calculating the average value per unit of material, then multiply by the percentage of the holding cost and finally multiply by the quantity of material stored. In the last section, the total holding costs coupled between the MSP and the JSP are to be used as an objective, so it can be simultaneously minimized with optimization features.

Table 1 indicates that the model can be determined as valid and sufficient to represent material inventory management at PT XYZ in particular to produce cars (X1). It was revealed that the model has the numerical sensitivity toward safety stock coverage and lead time; thus, these parameters become decision variables that can be changed during the minimization process. Previous research conducted by Janamanchi (2011) showed that a decrement in holding costs and unfilled orders can be achieved by changing the safety stock coverage. In addition, according to Wedel and Lumsden (1995), a shorter lead time can lead to better customer service, fewer supplies, and higher efficiency, so that the optimal lead time remains important for gaining a competitive advantage. Research conducted by Wang (2012) on the supply chain of printed circuit boards also produced a similar conclusion, namely, that shorter lead time will reduce costs, one of which is related to the cost of holding inventory.

The range of possible change for each decision variable was taken from interviewing the company. Table 2 shows the decision variables, the actual value of which is the current condition in PT XYZ, and the minimum/maximum values.

Table 3. Simulation Result for Upward Trend before and after Minimization Process

Parameter	Value Before Minimization	Value After Minimization
JSP Safety Stock Coverage	5 day	5 day
MSP Safety Stock Coverage	8 day	5 day
Total Holding Cost	Rp18,819,560,560	Rp15,232,144,939
Accumulation Positive Backlog	1,305.96 Car	1.151,52 Car
Accumulation Negative Backlog	-48.58 Car	-50.34 Car
JSP Lead Time	1 month	0.84 month
MSP Lead Time	1 month	0.84 month

Table 4. Result of Sensitivity Test for Minimization Process in Upward Trend

Parameter	Value with 7% Growth	Value with 21% Growth
JSP Safety Stock Coverage	5 day	5 day
MSP Safety Stock Coverage	5 day	5 day
Total Holding Cost	Rp13,991,208,036	Rp16,407,506,942
Accumulation Positive Backlog	954.58 Car	1.201.85 Car
Accumulation Negative Backlog	-55.42 Car	-49.42 Car
JSP Lead Time	0.77 month	0.77 month
MSP Lead Time	0.77 month	0.77 month

The first scenario assumes that consumer demand faces an upward trend with each month's request remaining volatile. In 2016 the Minister of Industry, Saleh Husin, in a Gaikindo report (2015) targeted automobile industry growth at 5.7%. According to Noergadjito as General Secretary of Gaikindo in Gumelar (2015), the growth of the car industry roughly followed the growth of Gross Domestic Product (GDP). The comparison is 1% to 1.5%; that is, when the Indonesian GDP grew by 5%, then the growth of the car industry reached 7%–7.5%. The interviewee from the YSO also said that they are considering the calculation from Gaikindo, and the percentages that given are still acceptable or possible to happen. For 2017 the International Monetary Fund (IMF) in Statista.com (2016) estimates Indonesia's GDP grew by 5.3%. By using a simple calculation, the growth of the automobile industry in 2017 is assumed to be 7.95%. Thus, in the simulation for two years from March 2016 until February 2018, car industry growth is assumed to be 14.1% (the percentage of the first year 5.7% multiplied by the number of last year's production and the result multiplied by 7.95%). The growth also is assumed already to cover the fluctuations in fuel prices, inflation, and others. Looking from the historical data, this assumption is still acceptable and has little difference. The method used is seasonal forecast while randomizing the demand pattern, so it will have upward trend. Table 3 shows the results of the simulation, prior to the process of minimizing holding costs and both negative and positive backlog, with total holding cost weight at 40% while both were, respectively, 30% and also after minimization process is conducted. There is a decrement in total holding cost, which amounted to Rp3.587.415.630 or about 19% during the simulation period. Accumulated negative backlog increased two units, but in the aggregate value of the absolute backlog (total accumulation of positive backlog plus accumulation of negative backlog), there is a decrement from 1354 units to 1201 units, or approximately 11.3% during the simulation period.

After the first scenario simulations, a sensitivity test was conducted to see whether there will be significant changes in the results of the minimization process if the percentage growth of the automobile industry changed. The first is to assume if the percentage growth in the car during the simulation period is only half that assumed or about 7%, while the second is if the growth

of the automobile industry during the simulation period rose 50% from the initial assumption, which is 21%. The results are shown in Table 4. From the simulation results, it seems that the safety stock coverage is at the same level as the initial assumption. As for the lead time, the differences range around 0.07 months from initial assumptions, or, if we count it in days while assuming one month equals 20 working days, the difference is only 1.4 days. From these differences, the company also may consider other factors that affect lead-time and adjust to the growing conditions the car industry. Insert Table 4 here.

To conduct the process of minimization, the decision variable will be equal to that shown in Table 2. From the results, it can be seen that there is a decrement in total holding costs, around Rp2.910.471.590 (19.41%). The aggregate value of absolute backlog also declined from 584 units to 504 units, or approximately 13.69%. From the results, it appears that the JSP and MSP safety stock coverage is at the same level as the result of the minimization process in the upward trend scenario, which is five days. But for lead time, there is a change to 0.82 months prior to the minimization process, which is one month.

The sensitivity test is then conducted for the same reason. The first is to assume if the downward percentage in car demand during the simulation period is only half of the first assumption, or approximately 6.5%, while the second is if the downward percentage in car demand during the simulation period rose 50% from the initial assumption, namely, to 19.5%. The simulation results revealed that the safety stock coverage has the same value as the initial assumptions. As for lead time, there is a low difference compared with the initial assumption, only one day.

With the existence of two plans—planned order and revised order—then most likely the backlog will always be there. The most ideal way to eliminate backlog is making a more accurate forecast of production plans. But it is difficult for the demand with a dynamic nature, and also each forecast method has its own limitations (Sterman, 2000). Then, the company can create internal policies, which is to change the safety stock coverage and lead time delivery of goods to reduce the total holding cost and backlog, as shown in the previous section. Because the behavior from each simulation is largely synonymous, except for the difference in the amount of each parameter, while the demand with a downward trend is lower than the upward trend; thus, this section will only analyze the scenario with an upward demand trend. When comparing the before and after minimization process of MSP and JSP inventory, the difference will look like the graph in Figure 3.

The most obvious difference is in MSP inventory, which, once the minimization process is performed, looks lower in the graph. A significant change is caused by changes in MSP safety stock coverage, from eight to five days, and lead time from one month to 0.84 months. For JSP, changes only happen to lead time, which also became 0.84 per month, and the chart presents very little difference; further, the change did not have a significant impact in material supplies. Fluctuations in the MSP and JSP inventory happen because the companies buy and store inventory based on the demand in each month. Moreover, there is always a difference between the delivery rate and usage rate. This is quite reasonable for companies that are utilizing production with a pull system such as PT XYZ. For companies that are utilizing production with a push system, the manufacturing companies determine the level of production and delivery it to the distributor; the distributor then distributes it to the dealer or retailer. Thus, it is easier to manage inventory levels, and the difference of delivery and usage rate is easier to minimize.

Table 5. Simulation Result for Downward Trend before and after Minimization Process

Parameter	Value Before Minimization	Value After Minimization
JSP Safety Stock Coverage	5 day	5 day
MSP Safety Stock Coverage	8 day	5 day
Total Holding Cost	Rp14,991,826,535	Rp12,081,354,949
Accumulation Positive Backlog	540.34 Car	435.92 Car
Accumulation Negative Backlog	-44.17 Car	-68.87 Car
JSP Lead Time	1 month	0.82 month
MSP Lead Time	1 month	0.82 month

With the pull system, production plans begin with the dealers and retailers. Moreover, coupled with PT XYZ’s unique two plans, the planned order and revised order, the difference between the delivery rate and usage rate can be even greater.

From this research, it can be concluded that, using the company implemented JIT method, it is almost impossible to not store inventory. Uncertainties arise from the dynamics of customer demand and require companies to keep safety stock as a buffer, so the backlog can be low. The inventory graph also shows that inventory levels are almost never the same level as with the desired inventory. This is because the adjustment period has reached a one-month lead-time. When the actual inventory approaches a desired inventory, the desired inventory level in the next month also has been changed to follow the production plan in that month. Backlog also affects the production plan in the next month, so it will affect the amount of the actual inventory; thus, the inventory level can be above or below the desired inventory.

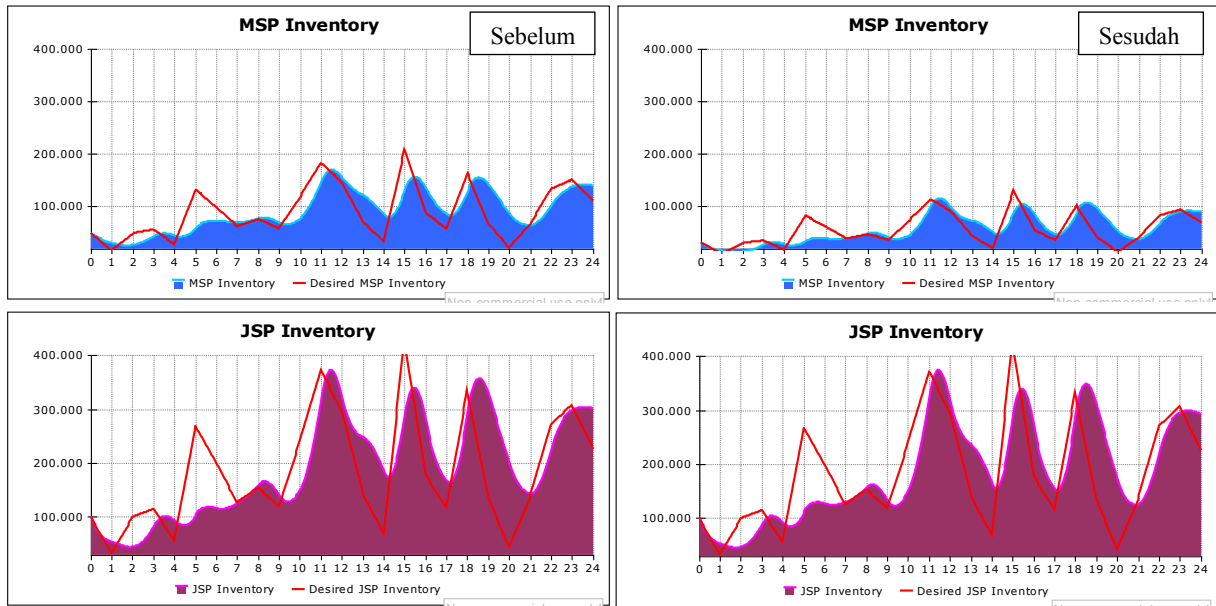


Figure 3. MSP and JSP Inventory in Upward Trend before and after Minimization Process

5. Conclusions

In this study, an internal policy, which can be taken by PT XYZ, in material inventory management to reduce holding costs and backlog is to change the safety stock coverage and lead time of material delivery. The results of the simulation both before and after the process of minimization and sensitivity test are as follows:

1. When demand growth reaches 14%, then the safety stock coverage of JSP and MSP is five days, while the lead time is 0.84 months. The results of a sensitivity test in minimization process when the trend of demand rose 7% and 21% indicate safety stock coverage JSP and MSP fixed at the rate of five days, with the lead-time at a rate of 0.77 months.
2. When the downward percentage of demand is 13%, then the safety stock coverage of JSP and MSP is five days, while the lead-time is 0.82 months. The results of a sensitivity test in minimization processes when the downward percentage of demand is 6.5% and 19.5% indicate the safety stock coverage of JSP and MSP fixed at the rate of five days, while the lead time, when downward percentage of 6.5% is 0.88 months and when the downward percentage is 19.5% at the level of 0.84 months.

All results indicate a reduction in the holding costs and also the value of the backlog, with an average reduction of holding costs at 19%, and the decrement in the backlog value is between 11% and 13.7%. Even though the fraction of holding cost changed from 27%, the results of minimization would be the same. The difference is only in the value of total holding cost. But safety stock coverage, lead time, the percentage of decrement in the total holding cost, and the backlog still hold the same value.

As the recommendation from the results of the minimization process, alternatives policies that can be taken by PT XYZ when facing the upward or downward trends in demand are: (1) Change the safety stock coverage to be as low as possible to an applicable level for the company, (2) Change the lead time delivery of material of both MSP and JSP by adjusting via the forecast of demand trend. When we calculate the average lead time for each scenario with the results of minimization process and sensitivity test, the policy alternatives we obtained are: (a) Upward trend scenario: JSP and MSP lead time is 0.793 each month, equivalent to 15.87 weekdays or rounded to 16 working days, and (b) Downward trend scenario: JSP and MSP lead time is 0.846 each month, equivalent to 16.93 weekdays or rounded to 17 working days.

Further research can begin with developing the model by considering the various existing constraints and assumptions. The limitation of this study is that we only analyzed the materials inventory management to produce one type of car. The model can be developed to analyze the company's products as a whole, so it will offer a more comprehensive picture. Other factors such as ordering cost, storage capacity, allocation on each production line, and other matters also can be considered.

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