Modeling Analysis in Furniture Company by Using System Dynamics

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Abstract

X Ltd. is a manufacturing company that produces office furniture, such as table, drawer, and office cabinet. Main raw material of office furniture products by X Ltd. is particle board. Errors in decision making in particle board supplies can affect the production cycle which has an impact on increasing waste, cost, and decreasing profit. The right decision-making analysis using the system dynamics model can help logistics manager in determining the right strategy in achieving optimal results while increasing company profits and minimizing costs. The AME calculation for model validation produces a value of 14.74% (raw material stock ready), 14.79% (customer demand), 4.65% (finished goods), and 7.48% (profit). The results of the system dynamics model simulation found that scenario 1 is the best decision scenario for company with average growth rates for raw materials of ready stock amounting to 644 pcs-2125 pcs, customer demand of 256 pcs-408 pcs, finished goods of 43 pcs-977 pcs, and profit of Rp. 794,879,346.00-Rp. 1,841,444,136.00.

Keywords
System Dynamics, Raw Material Stock, Furniture, Profit, Customer Demand

1. Introduction
Global furniture industries face difficulties in determining decision or policies that are faced with intence competition between furniture industries. The high level of competition between industries affect the determination of the company's warehouse inventory (Richard, 2012). Many industries will need optimal results according to the lack of knowledge and data on raw materials that need to be analyzed.

X Ltd. is a furniture manufacturing company that uses various raw materials to produce office furniture, one of raw material which is Particle Board (PB). X Ltd. produces many variations of products with a number of fluctuating sales from A-Class product to S-Class product. X Ltd. as a creative industry with a changing level of production makes it difficult in the decision-making process related to detemine optimal amount of raw materials.

Problem that found in X Ltd. is the frequent occurrence of errors in decision making related to the process of determine the optimal amount of raw materials. Based on the stock particle board data in X Ltd., the stock of PLM 012-200-PB types of particle board in April 2018 and June 2018 can't require the production requirement with stock numbers minus 11 units and 4 units, therefore logistics need to place an order suddenly. If this problem recurs, it can cause an increase in costs due to sudden ordering of raw materials, increased waste as a result of improper raw material stocks, and a decrease in profits due to production that is delayed or cannot be fulfilled. Therefore, it is necessary to do a simulation using the system dynamics model to determine the right strategy for the optimal decision on raw material inventory in order to answer various problems in the company.

2. Materials and Methods

The study was conducted in the X Ltd. which consists of in previous studies has been explained that X Ltd. usually get stock out of particle board that will be affect to supply and demand raw material, finished goods production, and etc. Analysis of X Ltd. internal and external sytem management with system dynamics model to show the relevance of raw material stock supply from supplier, finished goods production in production sector, raw material stock in warehouse stock, and the level of cost and profit.

3. Literature Review

3.1 System Thinking

Systems Thinking can help us to be able to understand and manage the complexity and uncertainty of the situation. As a paradigm, Systems Thinking is learning about effective action by looking at things as a whole compared to a separate part. According to Senge (1990), Systems Thinking is a framework for seeing reciprocal relationships rather than a state of being, for viewing patterns rather than static snapshots.

The initial requirement to start systemic thinking (Systems Thinking) is the awareness to appreciate and think of an event as a system (systemic approach) (Muhammadi et.al., 2001). According to Richmond (1993), the special expertise of system thinkers is interdependence and their specialization is to understand the dynamics produced by a system consisting of relationships that form a closed loop. Systemic Thinking (Systems Thinking) has 3 dimensions, namely paradigms, languages, and methodologies, based on that understanding so to produce systemic thinking, there are 5 steps that must be taken, namely (Soesilo, 2005):

1. Identify processes to produce real events.
2. Identify desired events (desired state).
3. Identify the gap between reality and desire.
4. Identify mechanisms for closing gaps.
5. Policy analysis.

3.2 System Dynamics

Modeling can be interpreted as a representation or abstraction of an object or actual situation. Other terms are called artificial real-world models made virtual. The model made must be analyzed further.
Dynamic model are model that can be developed to show changes in over time demand and supply. This model also reflects changes through simulation or based on real time and calculates components constantly by incorporating several alternative actions to come. The modeling process consists of the following steps:

1. Problem formulation and selection of real world boundaries.
2. Dynamic hypothesis formulation by establishing hypotheses based on behavior theory on problems and constructing causal structure maps through description of model with the help of tools, such as causal loop diagram (CLD) and stock flow diagram (SFD).

System dynamics methodology basically uses causal relationships in composing a complex system model, as a basis for recognizing and understanding the system's dynamic behavior. Problems that can be precisely modeled using the system dynamics methodology, namely:

1. Has a dynamic trend (changes over time).
2. The structure of phenomenon contains at least one feedback structure relationships.

4. Research Methodology

The research methodology begins with observing the company. The researcher found a problem in the warehouse stock which is often found to be experiencing shortages and strengths. Therefore, the company feels the need for improvement in the process of determining the raw material inventory strategy to meet the company's production in order to overcome existing problems. The research objectives to be achieved are as follows:

1. Analyze variables or factors related to the cause of problems in the company.Knowing the impact that might have an effect as a result of errors in the raw material warehouse area.
2. Collect data and determine the research method that will be used to answer the problem.
3. Designing a causal loop diagram of the factors that cause problems in the company.
4. Designing stock flow diagrams and simulating models from existing problem models.
5. Implement and analyze the application of scenario solutions from the system dynamics model.

The results will be validate using two methods: numeric validation and visual validation. Numeric validation is done by calculating Absolute Mean Error (AME) from reference data and simulation result data as decision making variabel. If the model is valid, thus data analyze is done to knowing what result will be found from data processing. Based on data processing that has done, modeling problems using system dynamics obtained scenarios that provide several alternative actions in assisting the decision making process to overcome problems that arise in the raw material warehouse area.

5. Result and Discussion

Causal loop diagrams designed consider various variables contained in the system both from internal and external companies as a form of evaluation of causal relationships between variables in order to know the root of the problem or the relationship of problems with possible solutions. On causal loop diagrams that have been designed, there are some variables that come from 6 (six) sectors. These sectors include suppliers, warehouse, production, shipment, internal company, and government.

Analysis of X Ltd. internal and external system management with system dynamics model begin with causal loop diagram. Causal loop diagram is a diagram that describes the relationship between variables in the system (Sterman, 2000). Causal loop diagram for X Ltd. system model can be seen in Figure 1.

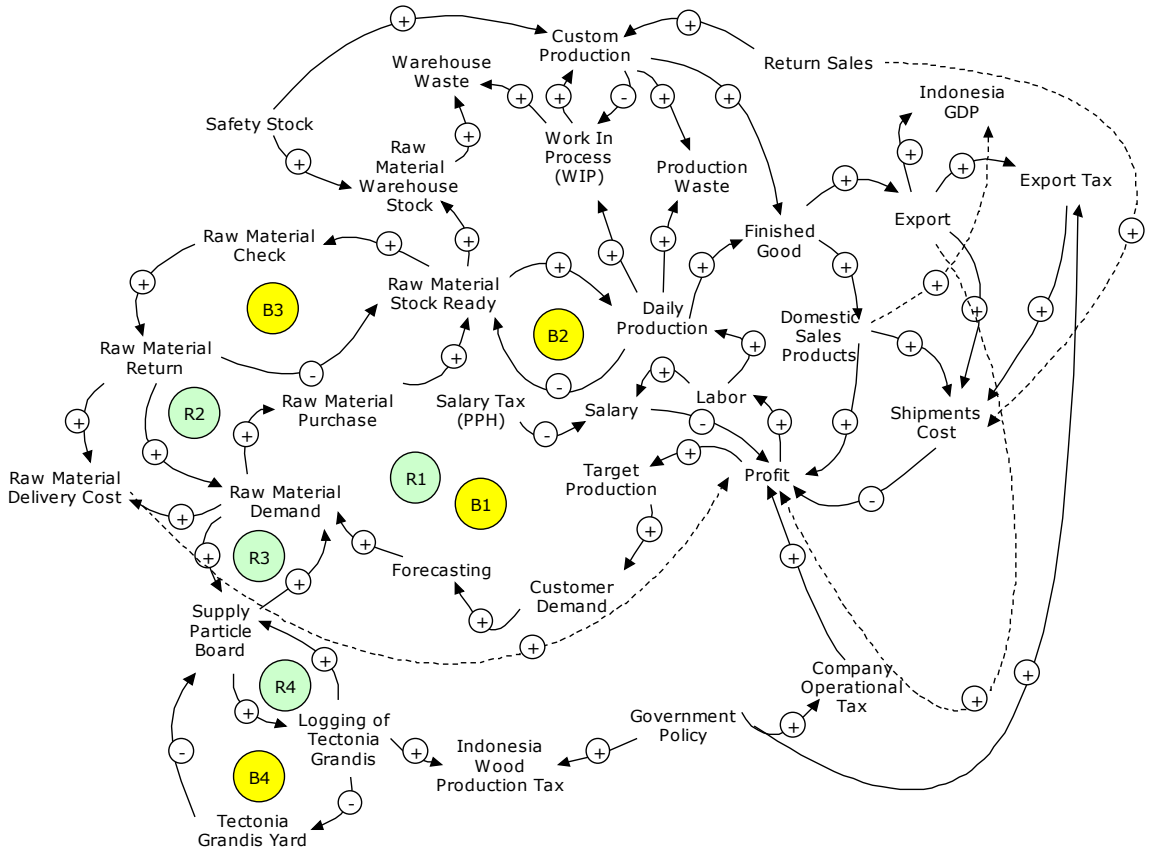

Figure 1. Causal Loop Diagram (CLD)

5.1 Simulation Result

Stock flow diagrams (SFD) are made based on causal loop diagrams (CLD) that have been made previously with the help of Powersim Studio 10 software. In SFD, variables that are used as levels in the simulation are presented in Table 1.

Table 1. Model Variable
(Source: X Ltd.)

Variable	Value
Raw Material Stock Ready	2100 pcs
Customer Demand	2200 pcs
Finished Goods	2057 pcs
Profit	Rp 3.760.196.000,00

Stock flow diagram for simulation of the overall system model from X Ltd. can be seen in Figure 2. Model formulation is done by providing units and formulas (mathematical equations) on the model that has been described in stock and flow diagrams obtained from the relationships between variables, historical data, and constants used by the company.

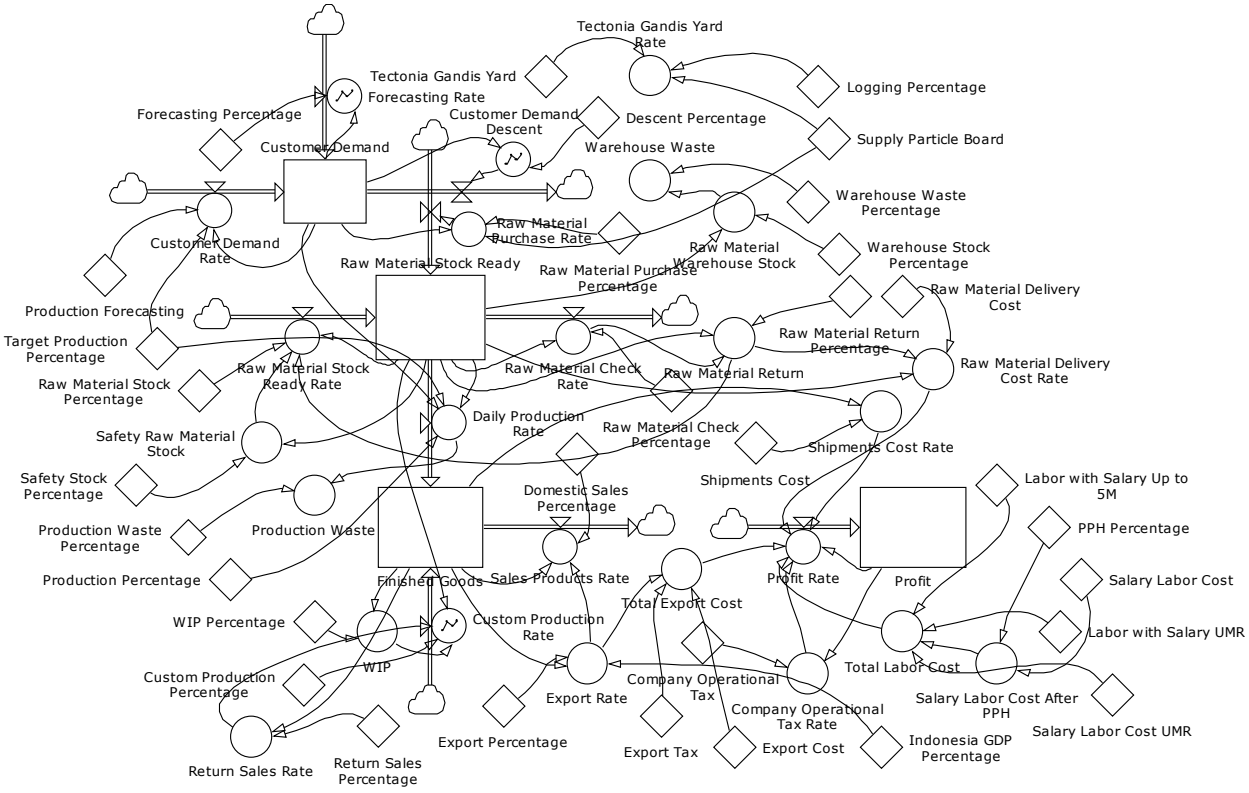

Figure 2. Stock Flow Diagrams (Actual Condition)

The result of raw material inventory model simulation in 2015-2017 can be seen in Table 2. The results obtained from the Powersim Studio 10 simulation, include the raw material stock ready level graph – profit – finished goods – customer demand.

Table 2. Model Simulation Results

Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
2015	2200	2100	2057	3.760.196.000
2016	2884	2773	4355	3.817.810.844
2017	3169	4862	4656	4.719.070.704

The following is a graph of the simulation results of X Ltd. for the period 2015 to 2017 which is presented in Figure 3.

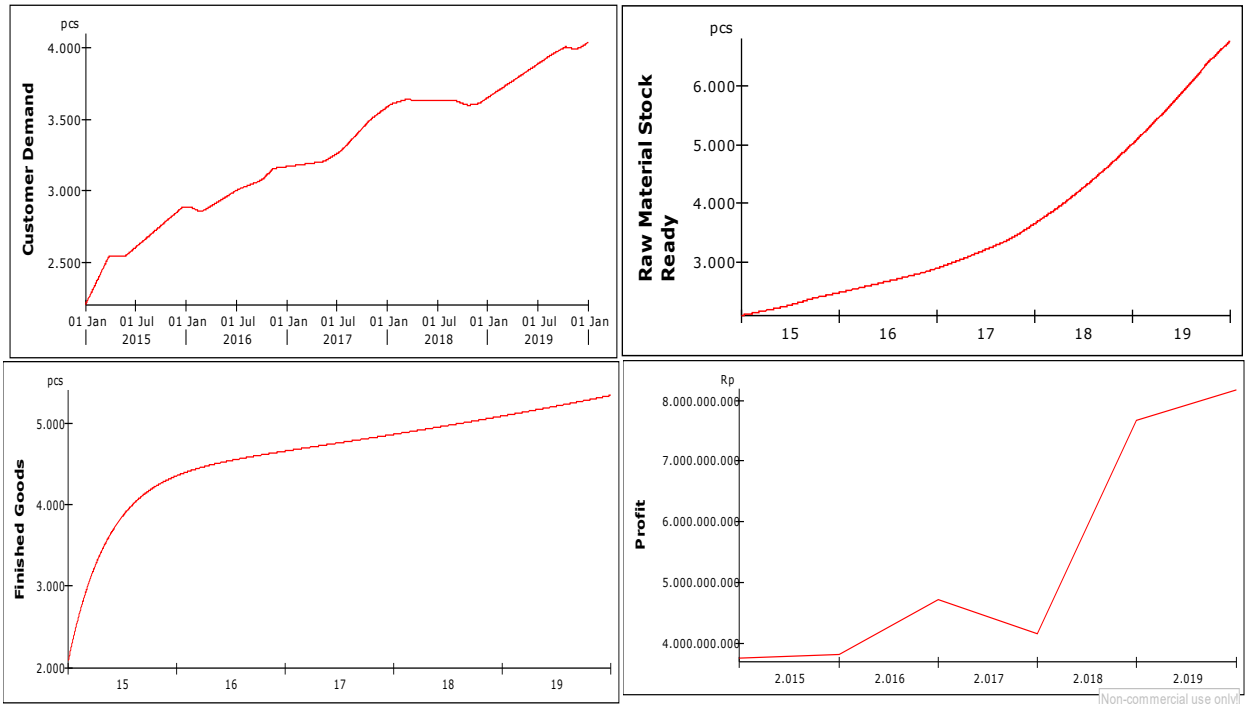

Figure 3. Model Simulation Results Graph

In Figure 3, it can be seen that simulation data for the level of customer demand has a fluctuating trend pattern as explained earlier that X Ltd. is a creative industry that has a changing number of consumer requests. However, the trend pattern of the raw material for stock ready has a GAP with trend in finished goods levels. This indicates that an error occurred in the raw material inventory strategy that did not meet production needs. This problem will have an impact on company profits as seen in the graph, the profit level has a downward trend starting from 2017 towards 2018.

5.2 Model Validation

The results of numerical model validation calculations (Table 3) in X Ltd. using Absolute Means Error (AME) are 14.74% for raw stock ready material variables, 14.79% for customer demand variables, 4.65% for finished good variables, and 7.48 % for profit variables. The validation results of the raw material level model of the stock ready and the customer demand level are declared valid because the validation value is still below the AME standard ≤ 30% for the field data of furniture manufacturing companies (which where some variable data cannot be controlled). Validation results of model level finished goods and profit levels are declared valid because the validation value is still below the AME standard ≤ 10% for controlled company data.

Table 3. Model Validation

Year	Raw Material Stock Ready (pcs)		Customer Demand (pcs)		Finished Goods (pcs)		Profit (Rupiah)	
	Actual	Model	Actual	Model	Actual	Model	Actual	Model
2015	2100	2100	2200	2200	2057	2057	3.760.196.000	3.760.196.000
2016	2612	2773	2642	2884	4300	4355	3.717.000.000	3.817.810.844
2017	4567	4862	3023	3169	4542	4656	4.520.000.000	4.719.070.704
Ave.	3093,0	3245,0	2621,7	2751,0	3633,0	3689,3	3999198666,7	4099025849,3
AME	**14,74%**		**14,79%**		**4,65%**		**7,48%**	
	Valid		**Valid**		**Valid**		**Valid**	

5.3 Business As Usual Simulation (BAU)

Business As Usual Simulation (BAU) conducted for 2018-2020 based on company expectations. The BAU model scenario is done by calculating the growth fraction for all based variables with reference data from the company. Raw material inventory model simulates several variables to look for growth trends per year. Model variables simulated in the BAU scenario can be seen in Table 4.

Table4. Variable of BAU Simulation
(Source: X Ltd. and Badan Pusat Statistik (Recorded by Researcher))

Variable	Value
RM Stock Ready	2100 pcs
Customer Demand	2200 pcs
Finished Goods	2057 pcs
Profit	Rp 3.760.196.000,00

BAU simulation of raw material inventory model for 2018-2020 can be seen in Figure 4 and Table 5.

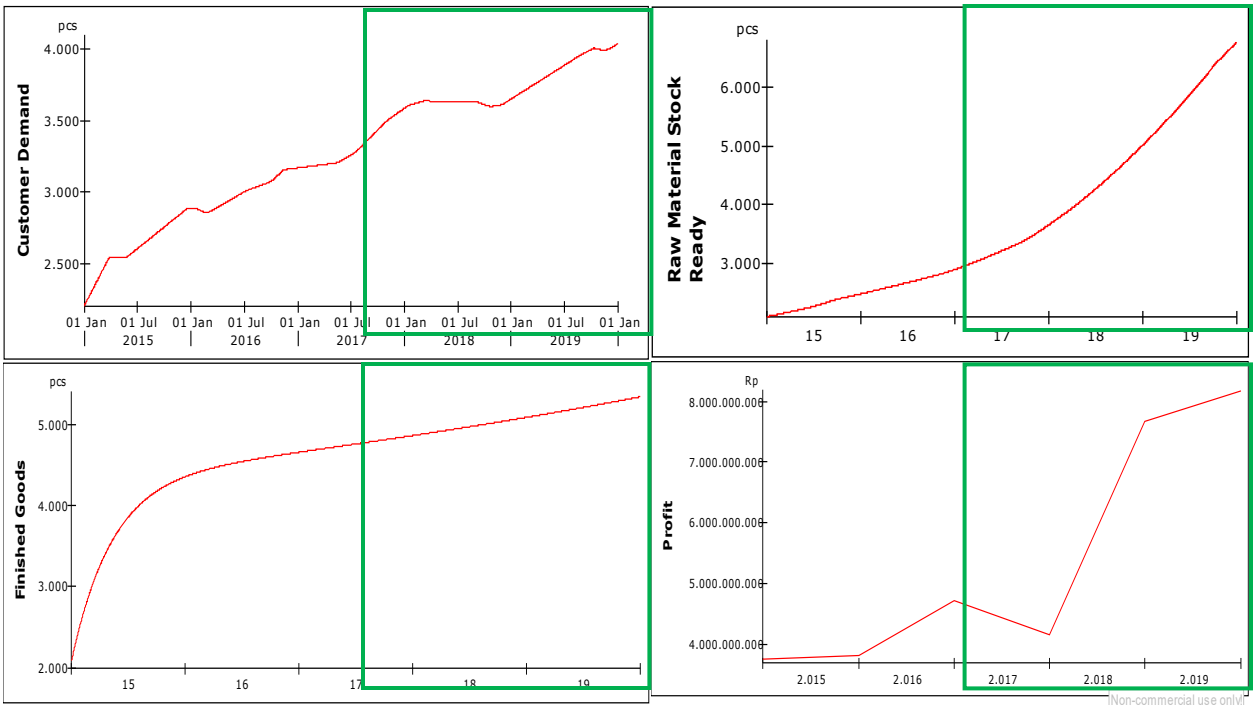

Figure 4. BAU Scenario Simulation

Table 5. BAU Result Simulation

Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
2018	3587	3659	4862	3.929.586.689,39
2019	3653	5016	5087	7.389.117.779,52
2020	4041	6765	5340	6.917.670.439,77

Based on the BAU simulation results in Table 5, there was an increase in profit in 2018 to 2019 in the amount of Rp 3,459,531,090.00. However, in 2019 to 2020, the company's profits decreased by around Rp 471,447,340.00. This is possible because of an error in determining the company's strategy related to raw material inventories and production plans. Therefore, intervention is needed on several model variables to design future scenarios (future scenario simulation) in order to determine the right alternative strategies to answer existing problems or achieve optimal results. The simulation results for level finished goods, customer demand, and raw material stock ready have a fairly stable upward trend.

6. Future Scenario Simulation

Based on the trend of data from the previous BAU scenario model, it can be seen that in 2018 to 2019, the company's profits decreased. The solution to overcome the things that might happen in the future is to determine the alternative strategies that can be applied by the company. Determination of alternative strategies can be done by designing future scenarios by intervening on several model variables that may be influential and can be controlled.

Interventions are carried out to achieve several objectives, namely increasing company profits and minimizing costs by optimizing the supply of raw materials in accordance with the production plan. In the X Ltd. management system model, the intervention produced 3 scenarios, as follows:

1. Scenario 1: Increase the profit level of the company by optimizing the number of raw stock ready materials through intervention in raw material return variables, raw material checks, raw material purchases, warehouse stock, warehouse waste, target production, WIP, safety stock percentage, and domestic sales percentage.
    a. Overcoming raw material returns or returning defective items to suppliers by increasing raw material checking by 10% from the initial conditions. Raw material purchase variable intervention is 5%. Intervention of these variables is the desire of the company.
    b. Overcoming the waste warehouse by increasing raw material checking and reducing raw material returns by 5% from the initial conditions. Reducing the work in process (WIP) level by 1% affects the level of warehouse waste as a result of reducing the WIP stack.
    c. Increase the company's production target by 2% which has an impact on increasing the company's domestic sales percentage by 10%.
2. Scenario 2: Increase the profit level of the company by optimizing the amount of raw stock ready material through the target production variable intervention of 7%, WIP by 0%, export percentage by 10%, and domestic sales percentage by 10%.
3. Scenario 3: Combined with scenario 1 with the addition of a labor variable intervention of 100 people out of 50 people the initial number of variables. The increase in labor numbers is believed by the company to influence the amount of production which has an impact on increasing profits. The intervention is also performed on the custom production percentage variable. This variable intervention is trusted by the company if the custom production number increases by 5%, it can affect the number of finished goods production that follows the trend of customer demand data.
4. Scenario 4: Increase the company's profit level by optimizing the amount of raw ready stock material through the raw material check variable intervention of 10%, raw material return percentage of 8%, safety stock percentage of 20%, custom production percentage of 5% and return sales percentage of 5%. The percentage reduction intervention in the return sales variable is believed by the company to reduce shipment costs and reduce production costs. Decreasing the percentage of sales returns causes the company to check the quality of finished goods production so that defects do not occur. Product defects begin with defects in raw material.

6.1 Scenario 1

The result of the intervention simulation scenario 1 is presented in Table 6.

Table 6. Result of Scenario 1

Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
2018	3634	3948	4677	4.253.545.450,31
2019	3890	4592	4720	5.048.424.796,00
2020	4042	6073	5697	6.889.868.932,20

The graph of the intervention scenario 1 simulation results can be seen in Figure 5.

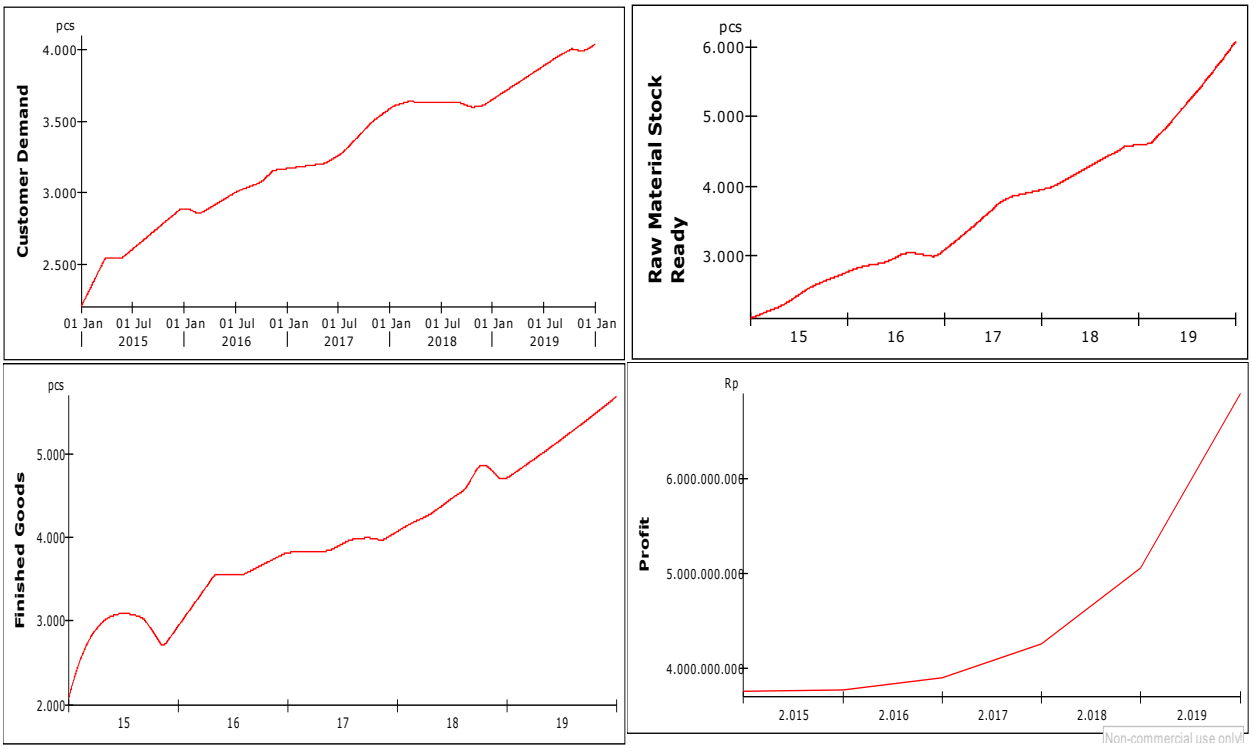

Figure 5. Graph of Scenario 1

Scenario 1 was designed by intervening in several model variables, namely raw material return, raw material check, raw material purchase, warehouse stock, waste warehouse, production target, WIP percentage, safety stock percentage, and domestic sales percentage. Based on the results of the intervention simulation scenario 1, it can be seen that the company's profit began to increase steadily starting in 2018 until 2020. The increase that occurred at the profit level was Rp 794,879,346.00 (2018 to 2019) and Rp 1,841 .444,136.00 (2019 to 2020). The level of finished goods has increased significantly with an average growth of 43 pcs-977 pcs. The customer demand level has increased steadily with an average growth of 256 pcs-408 pcs. The level of raw stock ready material has increased with an average growth of 644 pcs-2125 pcs.

6.2Scenario 2

The resultof the intervention simulation scenario 2 is presented in Table 7.

Table 7. Result of Scenario 2

Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
2018	3624	3748	6115	4.298.425.200,02
2019	3880	4692	6547	4.821.044.204,01
2020	4112	6043	8211	6.821.339.533,22

The graph of the intervention scenario 2 simulation results can be seen in Figure 6.

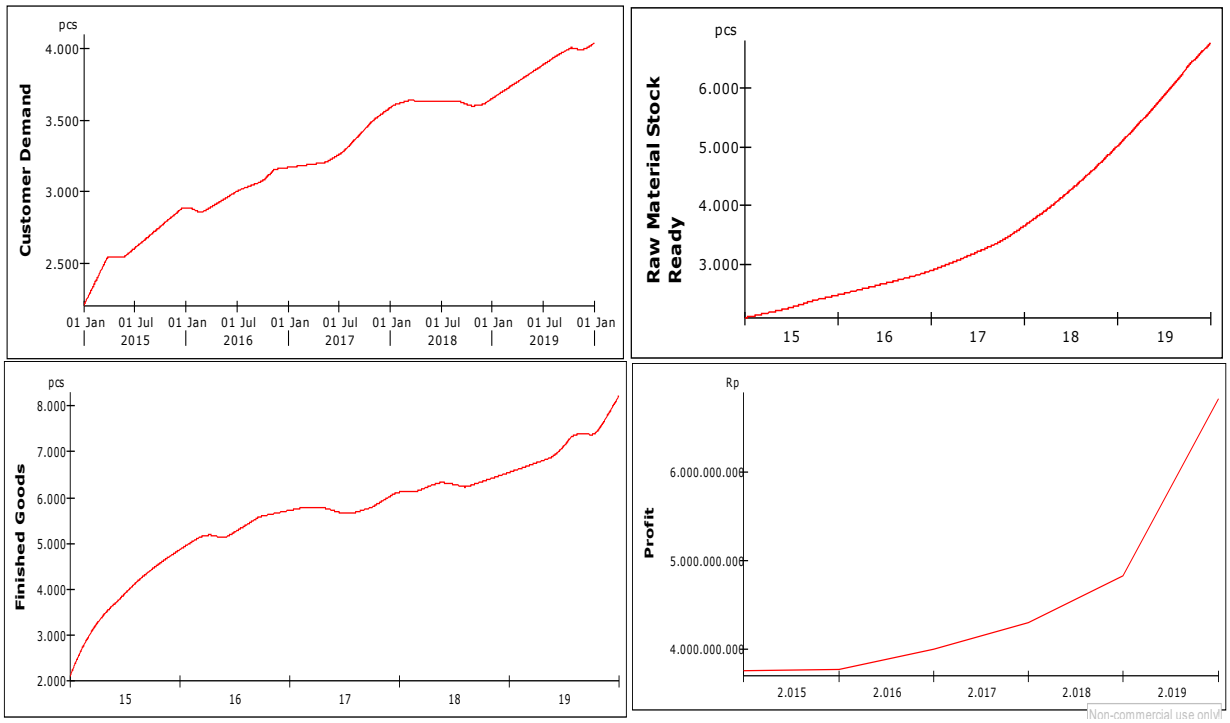

Figure 6. Graph of Scenario 2

In Figure 6, it can be seen the trend pattern of data for the graph of profit that rose sharply but was stable from 2018 to 2020. Data trends for level finished goods also increased steadily following the trend of data for the level of customer demand. The fulfillment of increased finished goods production requires the company to increase the amount of ready-to-produce raw material supplies needed to fulfill the production plan. The optimal inventory of raw materials reduces the amount of waste in raw material warehouse due to the rare discovery of excess raw materials as a result of the wrong determination of raw material inventories.

6.3Scenario 3

Scenario 3 was designed by intervening in several model variables, namely the variables intervened in the intervention scenario 1, labor variables amounting to 100 people out of 50 people the number of initial variables and the custom production numbers increased by 5%.The resultof the intervention simulation scenario 3is presented in Table 8.

Table 8. Result of Scenario 3

No.	Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
1	2018	3864	3968	4531	4.289.681.131,40
2	2019	3910	4672	4714	5.096.495.658,76
3	2020	4142	6173	5797	6.949.820.373,17

Graph of Scenario 3 intervention results can be seen in Figure 7.

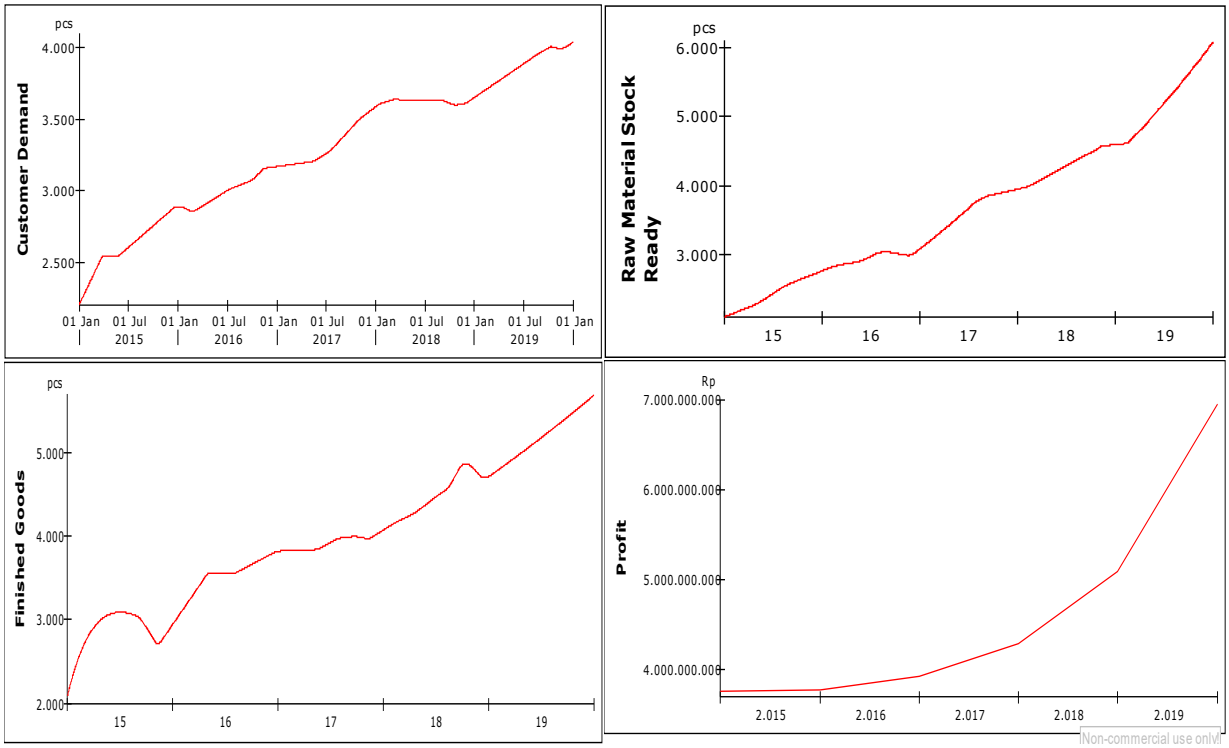

Figure 7. Graph of Scenario 3

Based on the simulation results of intervention scenario 3, it can be seen that the company's profits began to increase steadily starting in 2018 until 2020. The increase that occurred at the profit level was Rp 806,814,527.00 (2018 to 2019) and Rp 1,853 .324,471.00 (2019 to 2020). The level of finished goods has increased significantly with an average growth of 183 pcs-1266 pcs. The customer demand level has increased steadily with an average growth of 46 pcs-232 pcs. The level of raw stock ready material has increased with an average growth of 704 pcs-2205 pcs.

6.4 Scenario 4

The resultof the intervention simulation scenario 4 is presented in Table 9.

Table 9. Result of Scenario 4

No.	Year	Customer Demand (pcs)	Raw Material Stock Ready (pcs)	Finished Goods (pcs)	Profit (Rupiah)
1	2018	3864	3968	4531	4.329.581.231,40
2	2019	3910	4672	4714	5.133.425.558,76
3	2020	4142	6173	5797	6.429.520.473,17

Graph of Scenario 4 intervention results can be seen in Figure 8.

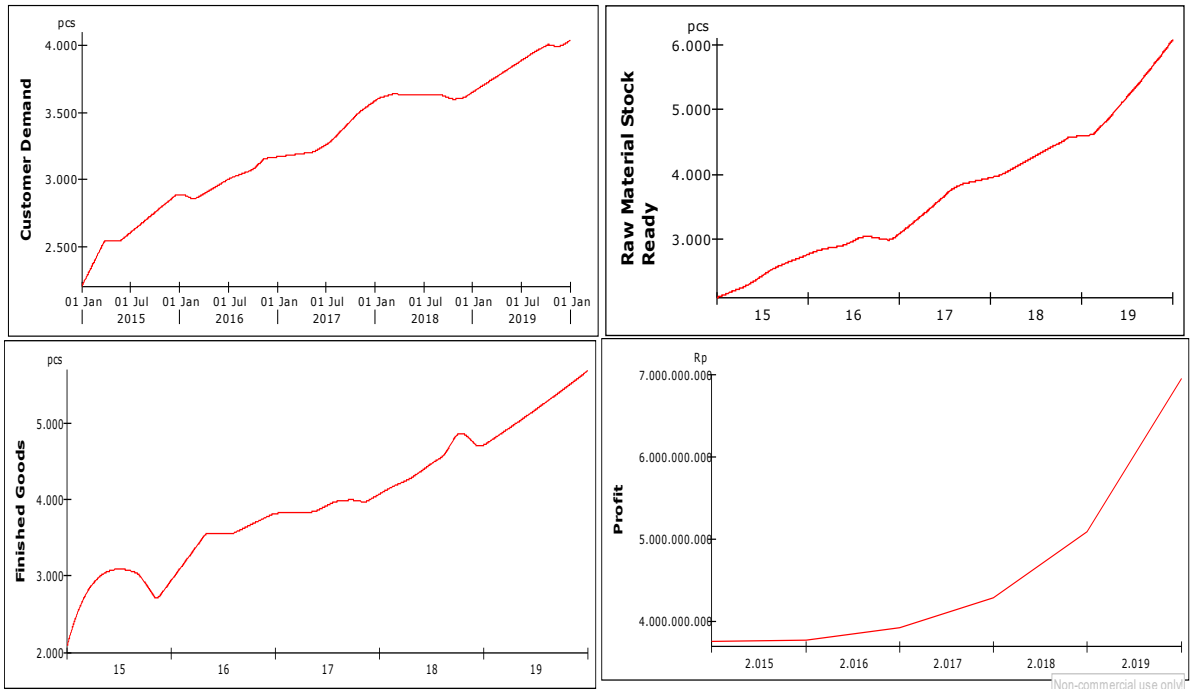

Figure 8. Graph of Scenario 4

7. Conclusion

Researchers produced conclusions and suggestions for the management of X Ltd.. Based on the analysis and discussion presented in the previous chapter, wecan conclude some of the following:

1. The BAU condition of X Ltd. management system projection model shows that in 2017-2018, X Ltd. experienced a decrease in the company's profit level of Rp 788,340,648.00 (starting from Rp 4,717,927,337.00 (in 2017) to Rp 3,929,586,689, 00 (in 2018)). The finished good level has steadily increased from 2015 to 2017 by 2057 pcs (in 2015) to 4656 pcs (in 2017) following the fulfillment of fluctuating customer demand of 2200 pcs (in 2015) to 3169 pcs (in 2017). Decreasing company profits in the period 2017 to 2018 causes company needs to simulate and design new alternative strategies to overcome problems, and increase output to the optimum point.
2. X Ltd. company profit increase is influenced by the number of optimal raw material stock ready that are able to meet the needs of finished goods production to meet customer demands. The minimization of waste warehouse, the level of raw material return, and the amount of WIP can reduce the cost of the warehouse and production section. Increased custom production, domestic sales, and export companies can increase the number of finished goods production companies and increase the number of company profits as a result of the many products sold to the market both locally (domestic) and overseas (export).
3. Alternative strategies to overcome crisis problems will determine the optimal raw material inventory to the level of finished goods production in meeting customer demand at X Ltd. is by intervening in raw material return variables, raw material checks, raw material purchases, warehouse stock, waste warehouse, production targets, WIP percentage, safety stock percentage, and domestic sales percentage.
4. The decision scenario chosen by the company is scenario 1 with the company's profit level starting to increase steadily from 2018 until 2020. The increase that occurs at the profit level is Rp 794,879,346.00 (2018 to 2019) and amounting to Rp 1,841,444,136.00 (2019 to 2020). The level of finished goods has increased significantly with an average growth of 43 pcs-977 pcs. The customer demand level has increased steadily with an average growth of 256 pcs-408 pcs. The level of raw stock ready material has increased with an average growth of 644 pcs-2125 pcs. The reason the company chose scenario 1 as the selected scenario was the trend in data for company profits and other levels that had a trend that increased stably and significantly than the other two scenarios.

References

Ackoff. (1994). *System Thinking and Practice*. USA: Institute of Technology.

Bertalanffy. (2002). *System Theory*. USA: MC Graw-Hill.

Blank, Leland. (1980). *Statistical Procedures for Engineering, Management, and Science.* USA: MC Graw-Hill.

Forrester JW. (1997). *Building a System Dynamic Model Part 1: Conceptualization*. Massachusetts: Institute of Technology.

Law, Averill M. and M.G. Comas. (1997). *Simulation of Manufacturing System*. Proceedings of 1997: Winter Simulation Conference, pp 86-89.

Law, Averill M. and W.D. Kelton. (2000). *Simulation Modelling and Analysis*, 3rd*edition*. USA: MC Graw-Hill.

McGarney B, Hannon. (2004). *Dynamic Modeling for Business Management An., Introduction.* New York: Springer.

P. Eykhoff. (1974). *Identification of Systems*. London: Wiley.

Peter, Senge. (1990). *The Art and Practice of TheLearning Organization*. New York: Doubleday Currency.

Purnomo. (2012). *Teori dan Komplesitas Sistem*. Jakarta: Gramedia Pustaka Utama.

Richardson, Udo. (2011). *System Dynamics: Theory & Practice*. Pensylvania: Ventus Publishing.

Soesilo, Karuniasai. (2014). *Pemodelan System Dynamics*. Jakarta: Gramedia Pustaka Utama.

Sterman, J. D. (2000). *Business Dynamics Systems Thinking and Modeling for a Complex World.* USA: Jeffrey J. Shelsfud. The McGraw-Hill Companies.

Takahashi, Y. (2003). *Translation from Natural Language Though Stockflow Diagram*. Japan: School of Commerce Senshu University.

Barlas, Y. (1996), *Formal Aspects of Model Validity and Validation in System Dynamics*. *System dynamic Journal Review*. Vol.12 Number 3Fall 1996.

Ibrahimy, Muhammad. *Design and Application of Radio Frequency Identification System*. *Internation Journal Conference On*, 1-6, 77. (2011): 1-6.

Badan Pusat Statisik Indonesia. (2015). Statistik Produksi Kehutanan 2015. Jakarta: BPS.

Badan Pusat Statisik Indonesia. (2017). Statistik Indonesia 2017. Jakarta: BPS.

Biography/Biographies

Kevin Oktavian is currently active as student of Industrial Engineering Department, Universitas Tarumanagara. Mr. Kevin was born in Jakarta, October 26th 1997. He started his higher education in Industrial Engineering, Universitas Tarumanagaraand will be graduated in 2019. His research interests are in System Dynamics and Modeling Field.

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Lilyana Jap is a contracted lecturer of Industrial Engineering Department at Universitas Tarumanagara since 2017, graduated from University of Indonesia, majoring on Environmental Science (industrial scope). Sheinterested with in-depth reasearch of modelling system with systems thinking methodes and system dynamics approachments. Her previous reasearch was using Powersim Studio 10, with utmos analytical about modeling in system dynamics.