Spare Part Inventory Management with a Cross-functional Perspective

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Abstract

This paper proposes an approach for spare part management that involves conflict of interests between units in a company. A case study of spare part problem in a cement industry used, which implicates five working units, called user, spare part planning, maintenance planning, procurement of goods and inventory management. The method used in this research is to classify spare parts into four categories by considering maintenance and logistics perspectives, then using system dynamic model to present the complexity in conflict of interest. This research expected to be useful for companies, particularly in managing conflicts in spare part management.

Keywords
Spare Part Management, Conflict of Interest, Inventory Policy, Dynamic System.

1. Introduction
Spare parts provided by management to reduce equipment downtime and play an important role in achieving the availability of desired equipment with minimum economic costs. This research takes a case in the cement industry where the parts procurement process involves several work units, the information obtained by each work unit has not been integrated in the decision making related to the exact number of spare parts needs and when these parts will be used resulting in conflict interests between these work units.

Some of the consequences arising from the conflict are the accumulation of a small inventory turnover ratio from year to year will lead to dead stock of spare parts. Then an increase in the average value of spare parts stored, obsolete of spare parts in warehouses because they not used for a long time while there is new technology because upgrading or replacing equipment is more sophisticated.

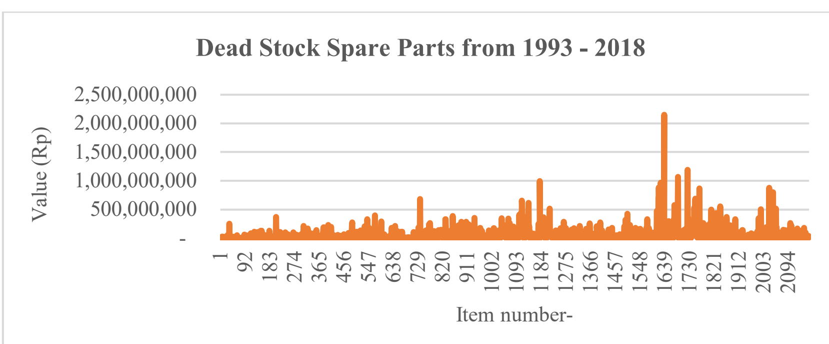

Figure 1. Graph of accumulation of dead stock spare parts since 1993 – 2018

As shown in Figure 1 above, there is a dead stock where the material has not moved since 1993 or since the establishment of the Factory until 2018, totaling 109 billion Rupiah or as many as 2,171 types or 18,629 pieces of spare parts with low turnover. The purpose of this research is to classify inventory to facilitate management in providing priority scale for parts, then analyse the effect of demand and use of parts at the inventory level using system dynamic simulations.

In classifying spare parts, several methods are widely used such as ABC Analysis, FSN Analysis, and VED Analysis. In this study, using VED Analysis combined with a logistics perspective in classifying parts. In analyzing the sensitivity of parameters that have been taken into account, a simulation is made to ascertain whether these parameters can be run in existing systems in the company given the complexity of the interests that exist within the company. Dynamic system simulation is able to accommodate the complexity of these interests given its ability to analyze a system in close-loop by considering the lead-time of arrival of goods and the time of use of spare parts.

2. Literature Review

With maintenance planning, maintenance costs are easier to control and reduce. Maintenance costs not only include labour and spare parts costs but also the cost of equipment downtime due to damage. Efficient and effective spare parts management is very important for maintenance management because it affects equipment downtime. Therefore, the management of parts manufacturing equipment affects the performance of maintenance management and, consequently, organizational productivity. In organizations with high dependence on production equipment, high availability of equipment is mandatory. Therefore, spare parts are an important resource to ensure availability.

VED classification (Vital, Essential, Desirable) using qualitative methods. The VED classification system based on knowledge from maintenance experts. Parts classified as vital, essential or desirable. Although it looks simple, structuring can be a difficult task because its implementation can be troublesome from the user's subjective assessment (Cavalieri et al. 2008). Lead-time is a relevant aspect to consider in the classification of parts. Logistically, there is a delay between the order of parts and their arrival.

Supply chain management consists of several sectors, one of which is inventory management, which is part of the company's internal work. If the company can manage the inventory system effectively and efficiently, it can produce a reduction in operational costs (Chopra and Meindl. 2007).

R, s, S inventory systems are a combination of systems (s, S) and (R, S). The idea is that every *R* unit time checks the inventory position. If it is at or below the reorder point *s*, then order an amount sufficient to raise it to *S*. If the position is above *s*, there is nothing to do until the next period (Silver et al. 2016).

To improve system thinking and system learning, systems must be modelled and simulated. There are six important steps in building a dynamic system model. Starting with identification and problem definition, followed by system conceptualization, model formulation, model testing and evaluation, use of models, implementation and dissemination as well as learning / strategy / infrastructure design (Martinez and Richardson. 2013). Such research has been conducted by Botha (Botha et al. 2017) dynamic systems. The automotive parts supply chain measures its success in terms of the availability of parts and stock needed to reach the target availability, measured as the fill allocation rate or Allocation Fill Rate (AFR). The supply chain strives to reach the AFR 95.5 % target by keeping stock levels low.

Other research that uses a dynamic system simulation approach for the case of bullwhip effect on inventory is conducted by Disney and Towill in modeling lean logistics where the researcher models causal loop diagrams for production and distribution systems in APIOBPCS (Automatic Pipeline, Inventory and Order Based Production Control System). The system has three controllers namely WIP, demand and inventory (Disney et al. 1997).

3. Conceptual Model

Based on Figure 2, the order of this study is to classify spare parts based on the criteria of VED, high price and high lead time. after being classified, class a is chosen for the use of the periodic review inventory policy R, s, S. Then tested on an existing system in the company with cross functions between work units. In conducting this research, several steps taken to make the system applicable and robust, such as the following steps:

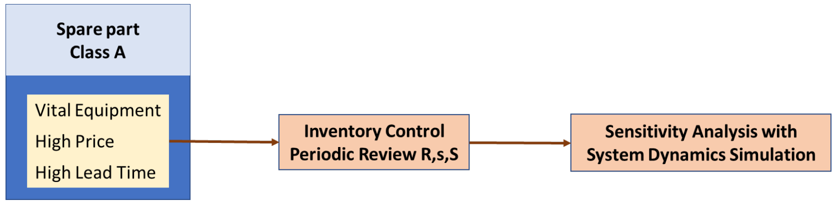

Figure 2. Research methodology

3.1. Classification of Parts by Considering the Logistics and Maintenance Aspects

This classification of spare parts carried out by Teixeira's previous research in 2018 that grouped the parts into four groups by considering the maintenance aspects in the form of criticality of a spare part using the VED Analysis method, then considering the logistical aspects of the price and arrival time of the parts from the supplier as shown in Figure 3.

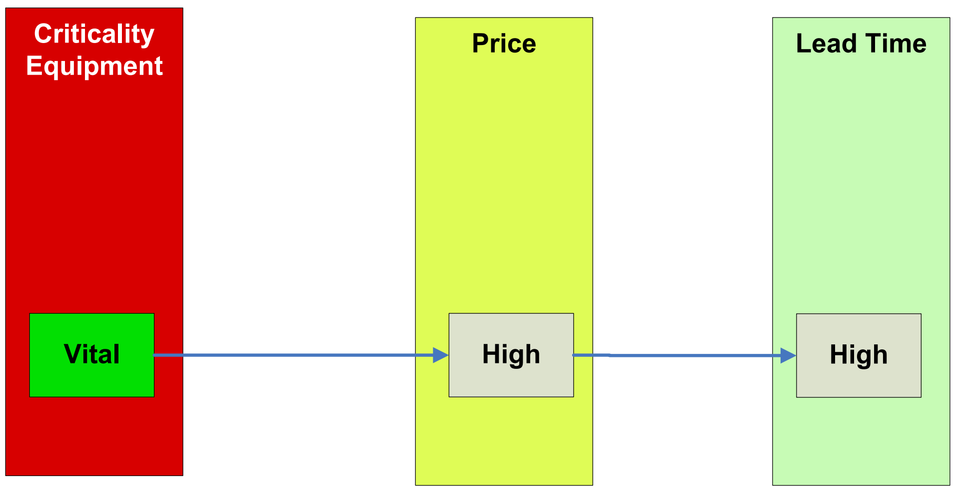

Figure 3. Decision tree spare parts classification 0.

3.2. System Dynamic Simulation

3.2.1. Conflict of Interest Inter Working Unit.

Figure 4 below is a diagram of the interrelationship between working units involved in spare parts management in this company. Starting from the process of requesting the purchase of spare parts in node 1.1 where the purchase request from the user will be processed by the parts planning work unit which will then be processed by the procurement work unit according to node 1.2 to be tendered to several related vendors.

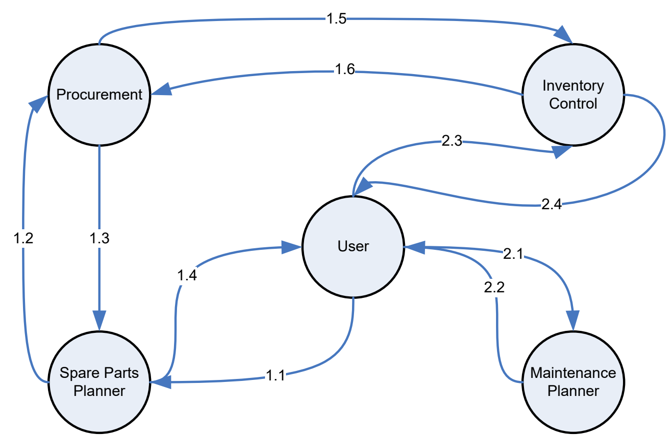

Figure 4. Influence diagram inter working unit.

However, before the tender process, the procurement party sees the inventory level for the spare parts, so that if the level is below the amount needed by the user then the process continues, and vice versa, if the level is above the user's needs, the tender process postponed first. In the tender process, from some of these vendors send a technical evaluation file to ensure the technical offer is in accordance with user needs. So that in node 1.3 the technical bidding document flows back to the spare parts planning and if it still technically needs confirmation to the user then the document flows to user according to node 1.4.

After the document confirmed by the user regarding specifications, lead-time, price and quantity, the document is returned to the spare parts planning to be forwarded to the procurement of goods for further processing, namely the price tender through e-procurement with the bidder is a vendor that meets the technical bid requirements. After there is a price tender winner, a Purchasing Order document appears with a certain lead-time until the item sent according to the tender agreement, the next process is the goods receipt according to node 1.5.

Whereas the goods issued process starts from node 2.1 where every month the user sends a plan for maintenance activities to the maintenance planning work unit as a comparison of the budget provided by the maintenance plan according to the maintenance activity plan. Then on node 2.2, the flow of information in the form of maintenance budget provided by the spare parts planning to the user to carry out spare part issued activities in the warehouse. At node 2.3 in the goods issued process, the user needs to flow information from the inventory management in the form of spare parts inventory level according to node 2.4. If the spare part level matches the user's requirements, the goods issued transaction continued.

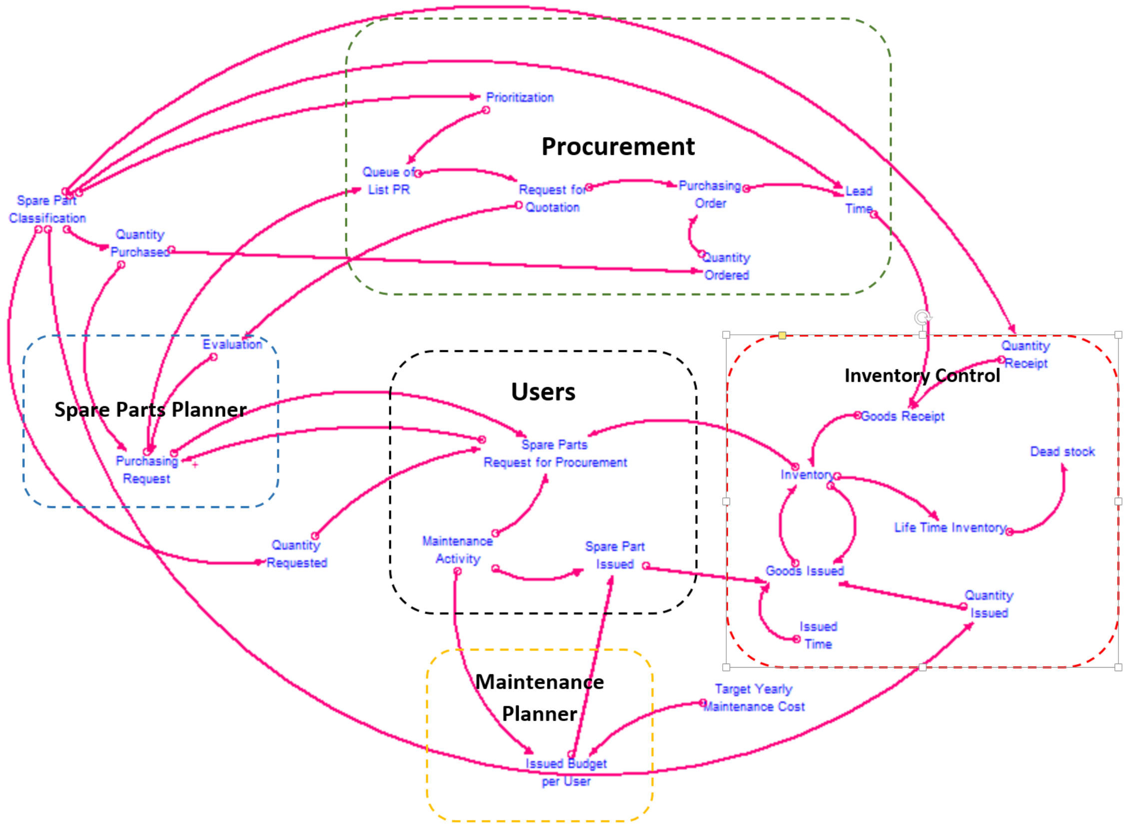

Figure 5. Conceptual model system dynamic spare part management.

The conceptual model of spare part management can be seen in Figure 5 above. The time of arrival or lead-time of spare parts at the warehouse determined by several factors. That is when the user makes a purchase request until the purchase request approved by the Head of the Maintenance Department. Then when the purchase request reservation processed into a Purchasing Request (PR) by the parts planning work unit until approved by Head of the Maintenance Department. Then when the PR processed by the Procurement Work Unit for Request for Quotation, then invites relevant vendors to make technical bids and prices. Then when the technical offer form evaluated by the parts planning unit, which sometimes needs confirmation to the user again. Then when to determine the vendor winner conveyed to the vendor until a Purchasing Order (PO) appears. Finally, the lead-time for the delivery of goods in this case the spare parts determined and accepted by the inventory management unit.

Meanwhile, the time to use spare parts or time for spare parts in the warehouse cannot be determined yet, so there is a big potential for the goods to become dead stock because they are obsolete or worn out and damaged due to life time. This usage time also depends on the budget that is owned by the user, if the budget is still available then spare parts can be taken from the warehouse and vice versa if the budget is not enough available then the spare parts cannot be taken from the warehouse. As a result, there are two polar opposites in the management of this inventory. On the one hand, it expected that the availability of spare parts is always available and on the other hand, even though spare parts are available, but if the User maintenance budget is not available, spare parts not taken from the warehouse with high potential dead stock. Based on the complexity that dynamic system simulation can provide solutions to maintain the balance of spare parts inventory value by taking into account the maintenance and logistics factors.

3.2.2. Model Development

System dynamic simulation is a continuous simulation approach that represents the world as a set of supplies and flows. In developing the current system between the work units involved in this research and to analyse the interrelationship it, stock flow diagrams used to analyse in more detail.

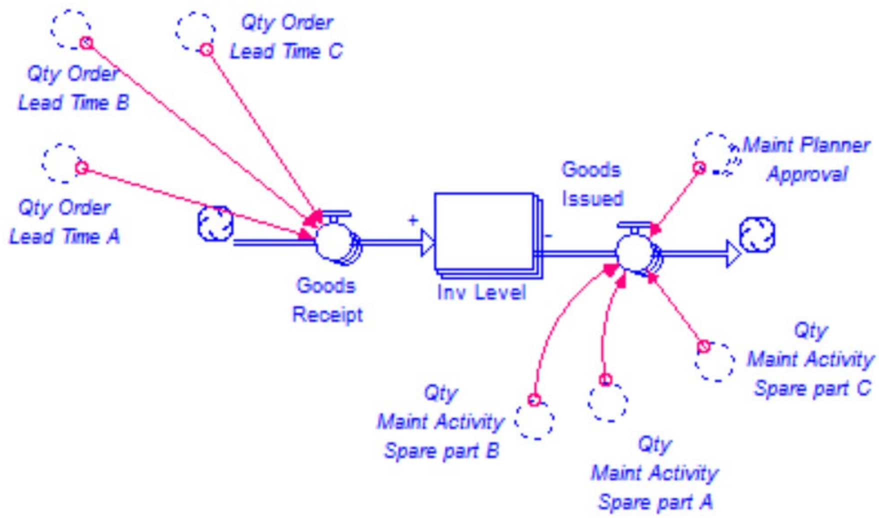

Figure 6. Sub-system goods receipt and goods issued all part

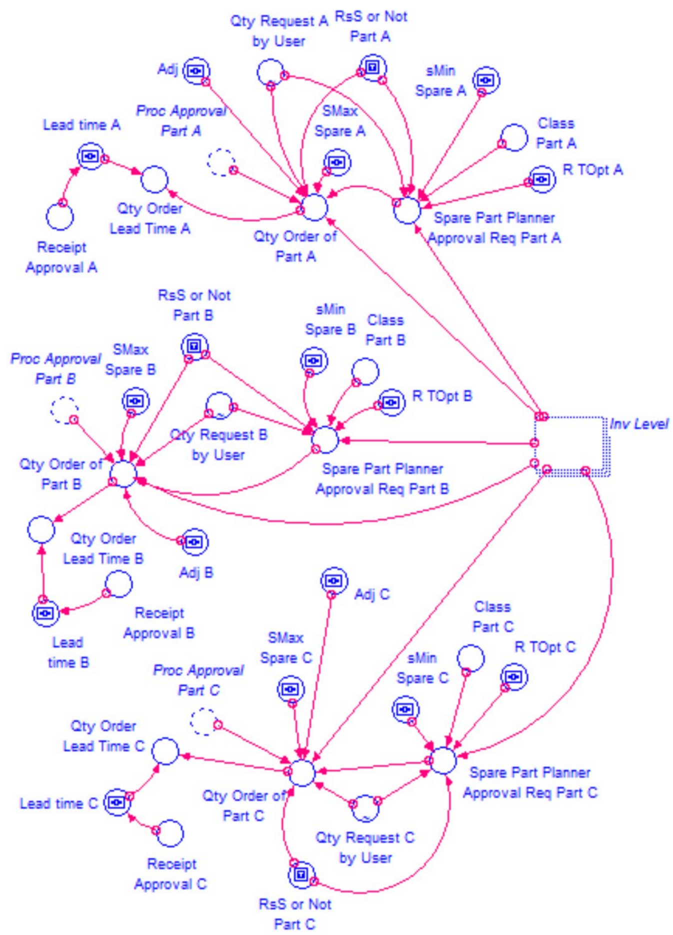

Figure 7. Sub-system goods receipt

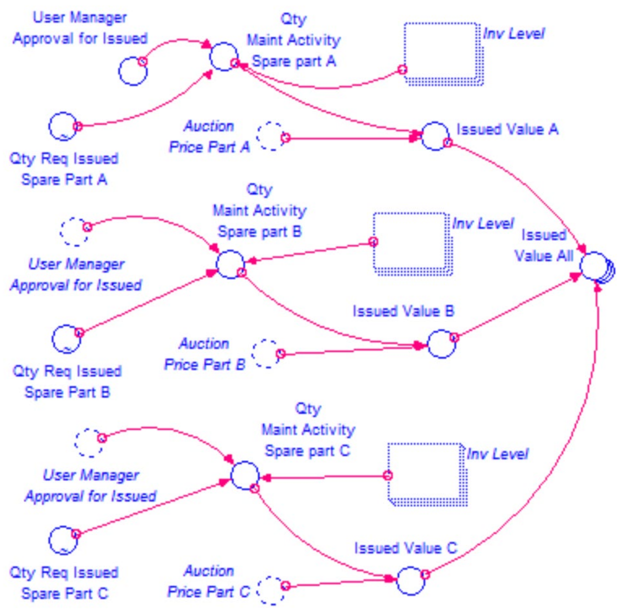

Figure 8. Goods issued all part

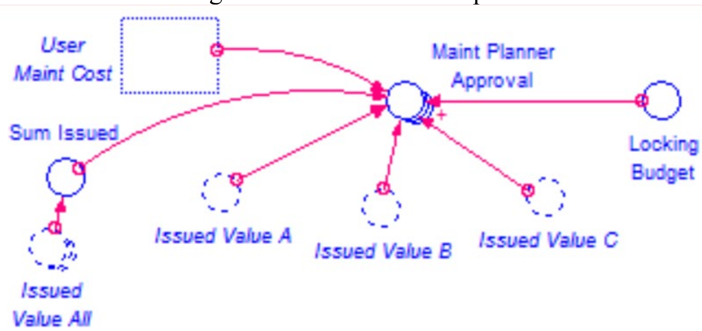

Figure 9. Maintenance planner approval

In Figure 6 and 7 above are system dynamics simulation in *Stella iseesystem* software that shows material flow starting from goods entering the warehouse (Goods Receipt) to parts out of the warehouse (Goods Issued). Goods Receipt or material entering the inventory influenced by minimum stock, maximum stock, interval optimum to review and inventory level itself, the amount requested by the user, the amount to be used by the user based on history, spare part classification, and parts planning approval.

The logic equation in the “Spare Part Planner Approval Request for Part A” flow is as follows:
if RsS or Not Part A = 1 then if Class Part A = 1 then if time/R TOpt A = int (time/R TOpt A) then if Inv Level[Part A] <= sMin Spare A then 1 else 0 else 0 else 0 else if Class Part A = 1 then if Qty Request A by User > 0 then 1 else 0 else 0

Whereas the logic equation in the *“Qty Order of Part A”* flow is as follows:
if RsS or Not Part A = 1 then if Spare Part Planner Approval Req Part A = 1 then if Proc Approval Part A = 1 then SMax Spare A-Inv Level[Part A] else 0 else 0 else if Spare Part Planner Approval Req Part A = 1 then Qty Request A by User + Adj else 0

Whereas the logic equation in the *“Qty Order Lead Time A”* flow is as follows:
DELAY(Qty Order of Part A,Lead time A-1)

Goods Issued or material coming out of inventory affected by inventory level, spare parts prices, and approval from maintenance planning. Approval of Maintenance Planning influenced by the price of spare parts and the limit once issued spare part transactions as locking budget variable, as shown in Figure 9 above. However, in carrying out goods issued, the user also limited by the budget that owned to run the operations of each work unit.

The logic equation in the *"Maintenance planner approval Part A"* is as follows:
if Issued Value A > 0 THEN IF Sum Issued <= User Maint Cost then if Issued Value A <= Locking Budget THEN 1 ELSE 0 ELSE IF (Issued Value A+Issued Value B) <= User Maint Cost THEN 1 ELSE IF (Issued Value A+Issued Value C) <= User Maint Cost THEN 1 ELSE IF Issued Value A <= User Maint Cost THEN 1 ELSE 0 ELSE 0

The logic equation in the *"Maintenance planner approval Part B"* is as follows:
if Issued Value B > 0 THEN IF Sum Issued <= User Maint Cost THEN IF Issued Value B <= Locking Budget THEN 1 ELSE 0 ELSE IF (Issued Value A+Issued Value B) <= User Maint Cost THEN 1 ELSE IF (Issued Value B+Issued Value C) <= User Maint Cost THEN 1 ELSE IF Issued Value B <= User Maint Cost THEN 1 ELSE 0 ELSE 0

The logic equation in the *"Maintenance planner approval Part C"* is as follows:
if Issued Value C > 0 THEN IF Sum Issued <= User Maint Cost then if Issued Value C <= Locking Budget THEN 1 ELSE 0 ELSE IF (Issued Value A+Issued Value C) <= User Maint Cost THEN 1 ELSE IF (Issued Value B+Issued Value C) <= User Maint Cost THEN 1 ELSE IF Issued Value C <= User Maint Cost THEN 1 ELSE 0 ELSE 0

In Figure 10 is the flow of maintenance costs obtained by each user based on the Budget Allocation per month compared to the quantity of user as working unit. This cost used by the user in carrying out goods issued at the warehouse. If the user does not have this cost, then it is certain that he cannot use the goods in the warehouse. The locking budget variable is the budget set by the Maintenance Planner to limit the user in one transaction taking goods in the warehouse

The logic equation in the *"User Budget for Maintenance flow"* is as follows:
Budget Allocation per Month per Department / Quantity User

Whereas the logic equation in the *"Cost of Material Issued"* flow is as follows:
IF Maint Planner Approval[Issued A] = 1 AND Maint Planner Approval[Issued B] = 1 AND Maint Planner Approval[Issued C] = 1 THEN Sum Issued ELSE IF Maint Planner Approval[Issued A] = 1 AND Maint Planner Approval[Issued B] = 1 THEN Issued Value All[A]+Issued Value All[B] ELSE IF Maint Planner Approval[Issued A] = 1 AND Maint Planner Approval[Issued C] = 1 THEN Issued Value All[A]+Issued Value All[C] ELSE IF Maint Planner Approval[Issued B] = 1 AND Maint Planner Approval[Issued C] = 1 THEN Issued Value All[B] + Issued Value All[C] ELSE IF Maint Planner Approval[Issued A] = 1 THEN Issued Value All[A] ELSE IF Maint Planner Approval[Issued B] = 1 THEN Issued Value All[B] ELSE IF Maint Planner Approval[Issued C] = 1 THEN Issued Value All[C] ELSE 0

Whereas the logic equation in the *"Maintenance Planner Approval"* flow is as follows:
If Issued Value All > 0 Then If Issued Value All <= User Maintenance Cost Then If Issued Value All <= Locking Budget Then 1 Else 0 Else 0 Else 0

Whereas the logic equation in the *"Issued Value A"* flow is as follows:
Quantity Maintenance Activity Spare part A * Price of Spare Part A

Whereas the logic equation in the *"Issued Value All"* flow is as follows:
Issued Value A + Issued Value B + Issued Value C

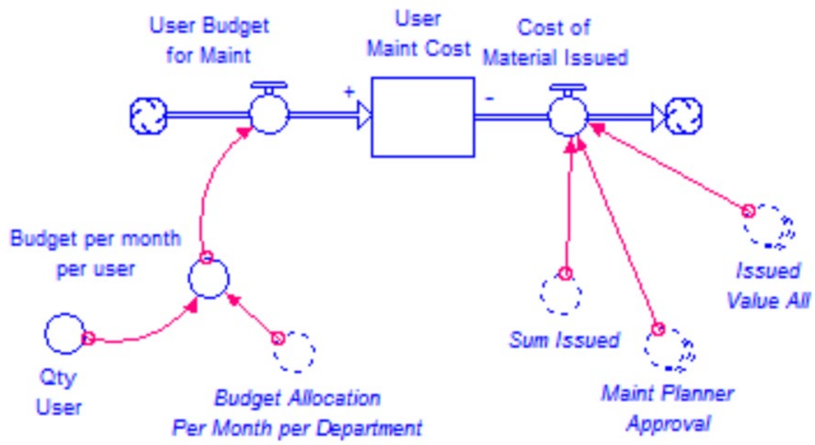

Figure 10. Sub-system user maintenance cost

The budget that owned by each work unit for maintenance of production equipment is influenced by the budget that has been allocated every month based on the history of the use of spare parts for each work unit from the previous period, the maintenance plan for that year and management policies in providing a budget to run production operations. As shown in the Figure 8.

Based on Figure 11, each department has a budget obtained from management policies, the value of inventory that is available in the annual period and maintenance planning. While the factors that influence the reduction of the department maintenance budget is the budget history in the previous period compared to the department maintenance budget.

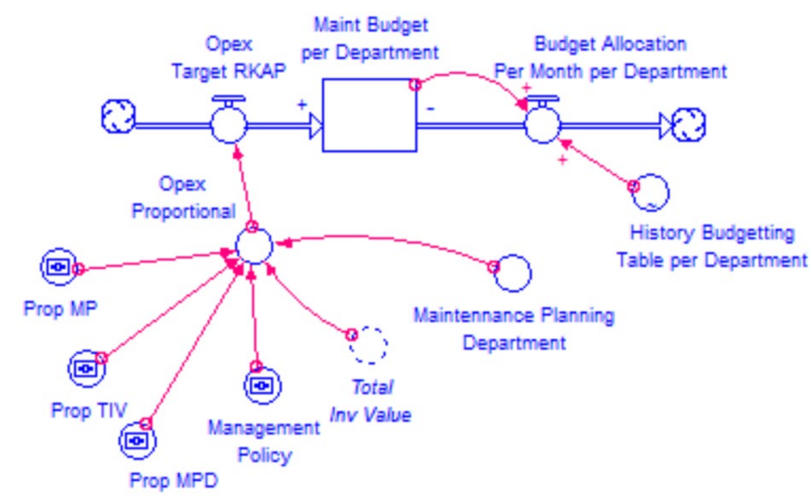

Figure 11. Sub-system department maintenance budget

Figure 12 is the flow inventory value that is the multiplication between inventory level and spare part price. This inventory value used to calculate the percentage of the budget that must give to each department in making improvements to the production machine each period. So that the budget not only considers company policy but also considers the value of spare parts inventory. Moreover, that can reduce the value of inventory is the activity of goods issued obtained from the activities in Figure 6.

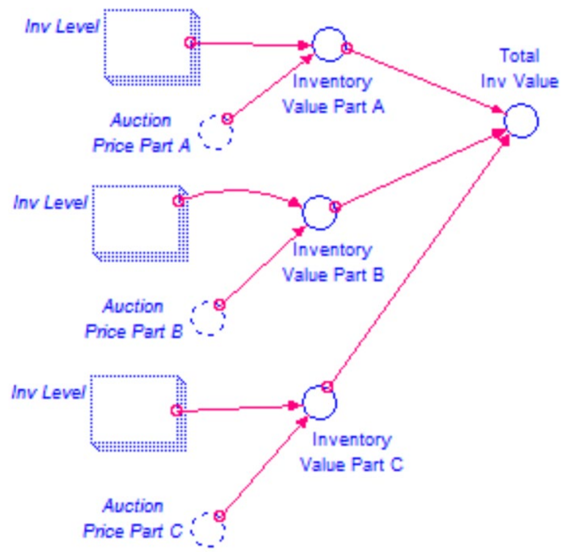

Figure 12. Sub-system inventory value

4. Results and Discussion

4.1. Inventory Level

This research is an initial model to represent the interaction of each work unit involved in spare parts management. In Figure 13 is a comparison chart between inventory level with goods receipt and goods issued in accordance with Figure 6. Simulation data in the form of spare parts demands for 72-month periods. Then the data calculated from the reorder point value, target stock level and the optimal period used to determine the exact time in the request to buy spare parts. *"Quantity Part Issued"* which represents the request for parts issued at the warehouse made by the User. In certain periods when there are no parts issued and no demand for spare parts, the inventory level is a stable value.

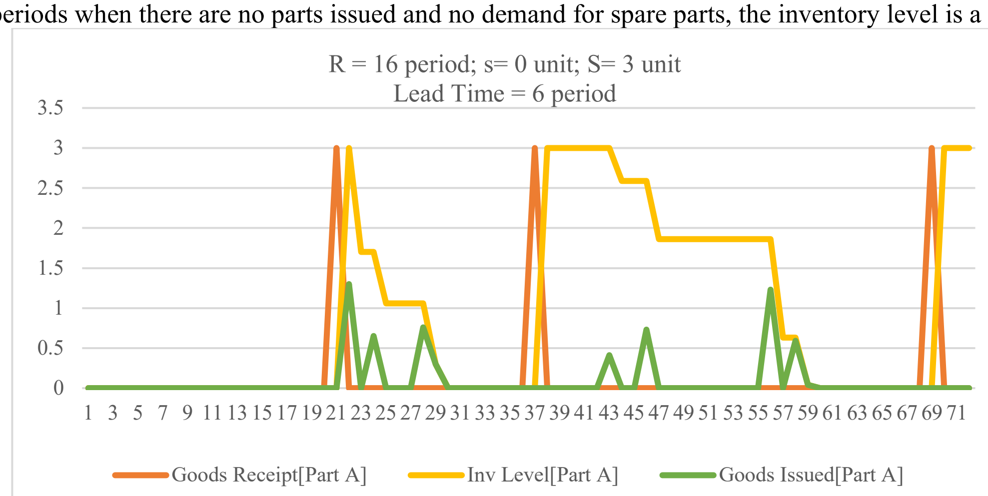

Figure 13. Inventory level chart

4.2. User Maintenance Cost

Figure 14 is a chart that represents the maintenance costs given to each user in managing their maintenance activities related to issued parts. The user budget for maintenance is obtained from the planned maintenance activities for a year and based on the history of activities in the past year period according to Figure 10. The accumulation of User Maintenance Cost is increasing because there is a sum of planned maintenance activities between the previous period and the current period. This value used to ensure that users can issued parts while they have a budget.

Based on Figures 10 and 11 above the user maintenance cost is influenced by the proportion of management policies, maintenance planning and inventory value. in this simulation the proportion of the three is 0.5; 0.2; 0.3 so as to produce the following graph.

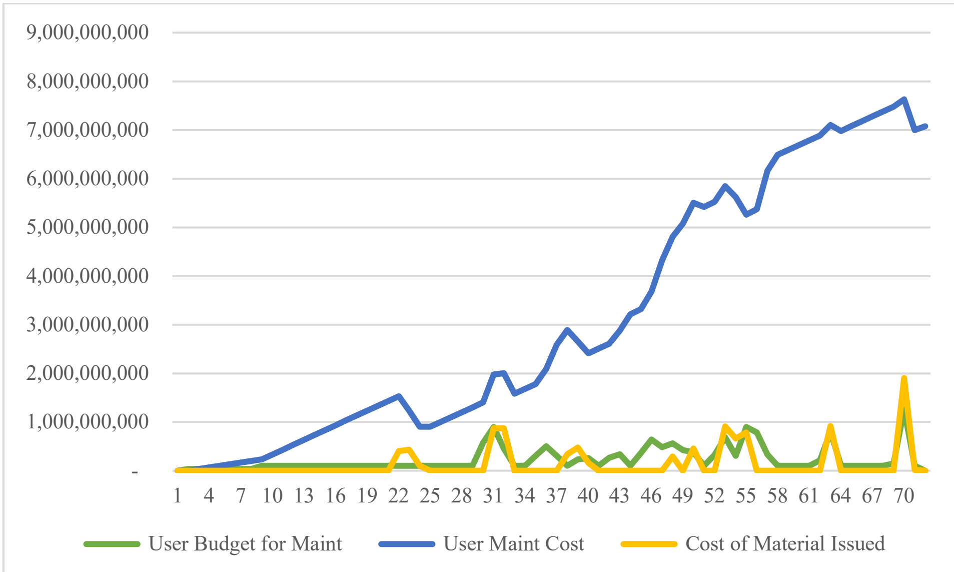

Figure 14. User maintenance cost chart.

4.3. Department Maintenance Budget

Figure 15 represents a comparison chart between the budget maintenance department and the Opex target and the Budget Allocation per month. In the period when an increase in the value of the department maintenance budget caused by an increase in the overall inventory value, it is expected that by increasing the maintenance department's budget, the activity of goods issued will increase so that it can reduce inventory levels according to Figure 12.

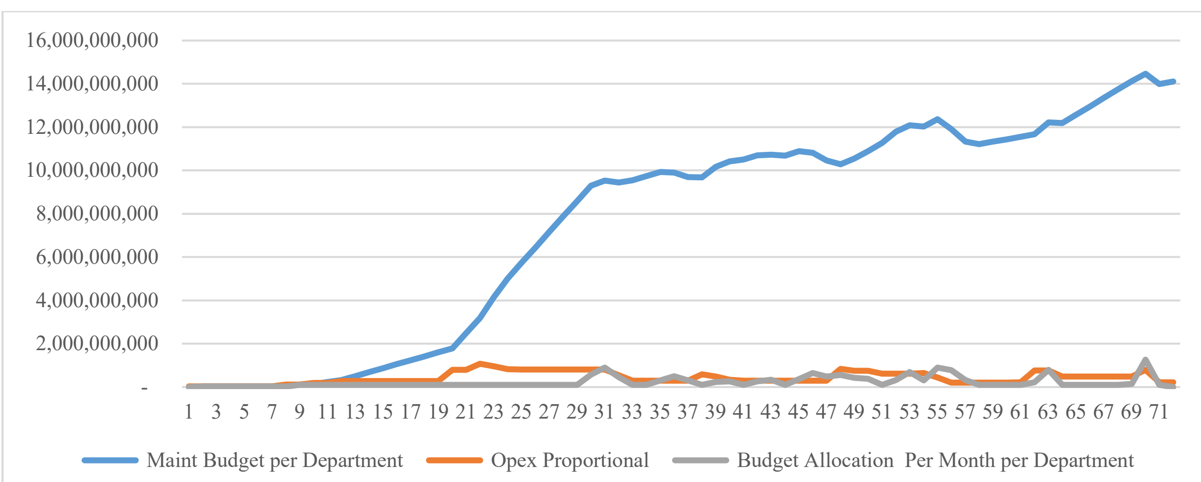

Figure 15. Department maintenance budget chart

4.4. Inventory Value

Figure 16 represents the Inventory price, where the value depends on the inventory level or the number of spare parts in the warehouse multiplied by the value of the spare part. This value is inversely proportional to Goods issued, i.e. if the value of goods issued is high, the inventory price will go down, and vice versa.

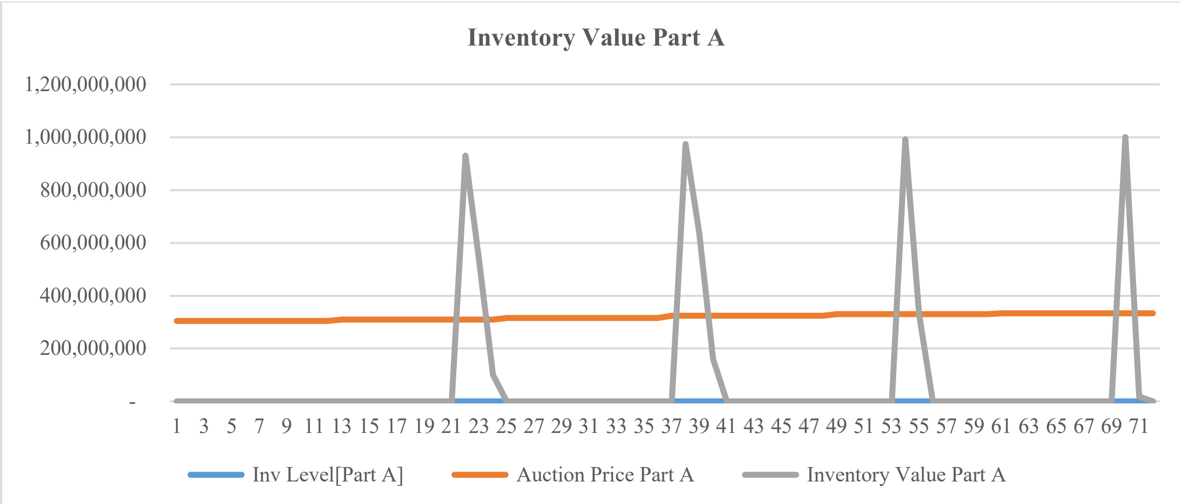

Figure 16. Inventory value chart

5. Conclusion

By applying a periodic review inventory control R, s, S, the user does not need to plan for continuous purchases because the inventory system is able to make purchase orders automatically provided that the parts are still needed by the user. The system will monitor when buying spare parts based on inventory levels that depend also on the use of spare parts in the warehouse. The use of spare parts depends on the budget provided by management, whether it only considers management policies or also considers the value of inventory as well. If considering the value of inventory, it is expected that every budget period given consider the spare parts in the warehouse can be used so that it can reduce the deadstock of spare parts in the warehouse

Based on the system dynamic model made, in deciding the number of purchases for each of these parts, it must also take into account the estimated parts that will used in the same period. Whereas in deciding or estimating the amount of spare parts usage in the same period, the budget for each equipment maintenance unit must take into account the budget. Then the budget of each work unit for maintenance of production equipment is given based on management policies related to the budget allocation given in one year to a production plant, then based on the history of the use of the budget and planned maintenance activities that use spare parts in the warehouse.

This research is able to represent the dynamics in spare parts management that does not necessarily consider the spare parts classification approach and inventory policy. Nevertheless, other factors can influence management decisions in providing spare parts. The approach uses a system dynamic simulation.

References

Botha, A., Grobler, J., Yadavalli, V.S.S., System Dynamics Comparison of Three Inventory Management Models in an Automotive Parts Supply Chain, *J. Transp. Supply Chain Manag.*, AOSIS, 2017 Mar 30, vol. 11, 2017.

Cavalieri, S., Garetti, M., Macchi, M., and Pinto, R., A Decision-Making Framework for Managing Maintenance Spare Parts, *Prod. Plan. Control.*, Informa UK Limited, 2008 May 19, vol. 19, no. 4, pp. 379–396, 2008.

Chopra, S., and Meindl, P., Supply Chain Management. Strategy, Planning & Operation, *Das Summa Summarum des Management*, Gabler, pp. 265–275, 2007

Disney, S.M., Naim, M.M., and Towill, D.R., Dynamic Simulation Modelling for Lean Logistics, *Int. J. Phys. Distrib. Logist. Manag.*, Emerald, 1997 Apr 1, vol. 27, no. 3/4, pp. 174–196, 1997

Martinez-Moyano, I.J., and Richardson, G.P., Best Practices in System Dynamics Modeling, *System Dynamics Review.*, Wiley, 2013 Apr, vol. 29, no. 2, pp. 102–123, 2013.

Silver, E.A., Pyke, D.F., and Thomas, D.J., *Inventory and Production Management in Supply Chains*. CRC Press, 2016.

Teixeira, C., Lopes, I., and Figueiredo, M., Classification Methodology for Spare Parts Management Combining Maintenance and Logistics Perspectives, *J. Manag. Analytics.*, Informa UK Limited, 2018 Feb 19, vol. 5, no. 2, pp. 116–135, 2018.