Dynamic modeling of an inventory system to minimize of inventory cost

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Abstract. Recently business competition is getting tougher, especially concerning the fulfillment of consumer needs. Unstable market demand is often a challenge for companies in fulfillment of market demand. The study was conducted at PT TSJ, and the problem is when the supply is higher than the demand, the company will have to bear the holding cost. Meanwhile, when inventory is lower than the demand, the company must bear the cost of a product backlog. This research uses a dynamic system method with three scenarios: real situation scenario, raising the safety stock and reducing lead time. Results of the simulation are based on a real situation that shows the lead time from distributors to retailers and distributor safety stock has a major effect on the costs borne by the distributor and the longer the safety stock; results of the increase of the safety stock scenario shows that the backlog costs are reduced but the product as inventory at the distributor increases and thus the saving costs increases, and the result of reducing the lead time shows that holding cost at distributor reduced. The conclusion of this research shows that the best scenario to minimize the total cost is to reduce lead time.

1. Introduction
Recently business competition is getting tougher, especially concerning the fulfillment of consumer needs. Unstable market demand is often a challenge for companies in fulfillment of market demand. Fulfilling consumer demand is the goal of every company. In an effort to meet this demand, the company carries out production activities supported by the company's supply chain activities. Increasing complexity of supply chain systems (which is the result of changes in customer preferences, the globalization of the economy and the stringy competition among companies), these decisions are often far from optimum [1]. With a good supply chain system of material, the company can fulfill consumer demand well, and it can increase the company's competitiveness in the market [2]. One important thing for it is an inventory system. To support a good inventory system requires collaboration and coordination from the supplier, the production department, and the distributor.

Inventory systems will affect company costs, and company costs will affect efficiency and competitiveness. Conditions of demand that are often more than inventory or vice versa incur costs that must be borne by the company [3]. It caused by a lack of collaboration and coordination between supply chains results in information distortion resulting in demand variability, this is commonly referred to as the bullwhip effect. The bullwhip effect is a condition that occurs in the supply chain where demand from customers changes (distorted). One of the most effective ways to solve the bullwhip effect is to share information across participants involved in a supply chain [4]. The effect by
which slow-moving consumer demand creates large swings in production for the suppliers at the other end of the supply chain [5]. The change resulted in a series of effects that would disrupt the supply chain.

When demand exceeds inventory, the company must meet the demand in the next period. The inability of the company to meet these demands results in product backlog costs. Conversely, when inventory exceeds consumer demand, the company must bear the cost of storing products. The bullwhip effect that has been explained previously causes the company to prepare products in excess of the incoming demand as safety stock. The existence of the safety stock is causing an increase in the cost of storage that must be incurred by the company.

Theoretically, supply chain performance can be measured using Performance of Activity (PoA): Cost, Time, Capacity, Capability, Productivity, Utilization, and Outcome [6]. Whereas performance measurement based on Key Performance Indicators some of which are based Misni and Lee; Habib M: customer satisfaction, throughput, delivery Lead Time, product availability on the market, costs/fees, and service innovation [7,8].

The study was conducted at PT. Tri Sapta Jaya which is engaged in the distribution of medical devices, medicines and formula milk. The problem that arises is when the supply is more than demand, the company will have to bear the holding cost. Meanwhile, when inventory is less than demand, the company must bear the cost of a product backlog.

2. Method
Based on a characteristic of the problem, this research uses a dynamic system method. Related with the supply chain as a complex system, this method considered suitable because it can accommodate the principle of nonlinearity, feedback loop, and delay of supply chain system [9]. For the simulation of the model, this research uses licensed Powersim 10 software.

The data needed in this study consists of primary data and secondary data. Data delivery mechanism, sales mechanism, and supply chain structure collected using the direct observation method; data about the cooperative relationship carried out by the interview method; then data about product sales data, production quantities, and sub-distributor data is done through a document study (secondary data).

Data processing is then performed by a dynamic system method that begins by describing a causal loop diagram to see the relationship between one variable with another variable and a stock-flow diagram to see the causal flow based on its quantity [10]. A dynamic model of the system using causal loop diagrams and difference equations is presented [11]. After the model is described both in terms of cause and effect and the quantity is then verified, that is compared with historical data so that the model created in accordance with its original state can be used for simulations [12]. The verified model is then simulated using licensed Powersim Studio 10 software to simulate various repair scenarios. The best scenario obtained from the simulation will be analyzed to find out how improvements can reduce costs compared to current costs. If the simulation results scenario has a lower cost than the current conditions, then the scenario can be chosen as a performance improvement in terms of cost.

3. Result and discussion

3.1. Data collection
PT. Tri Sapta Jaya (PT TSJ) is a distributor company that acts as a distributor of products produced by PT. Kalbe Farma Tbk. Products distributed include medicines, formula milk, and medical devices. These products are distributed to Pharmaceutical Wholesalers and sub-distributors around the City of Bandung. There are six distribution destinations carried out by companies around the City of Bandung, as follows: Abqari Medika, Alphatirta Medica, Central Bandung Raya, Inti Medicatama Results, Prima Anugerah and Sarana Bani Medical.
3.1.1. *Wide range of products.* As a distributor of medical devices, PT. Tri Sapta Jaya distributes various types of infusion needle. Products distributed by companies have a variety of sizes, namely 14G-24G. The larger the size number, the smaller the diameter of the needle. The selling price of the product set by PT. Tri Sapta Jaya for each size (including tax) is the same, which is IDR 26,000 per item. The same price is an assumption that the number of purchases, although different sizes, is still considered as the same product.

3.1.2. *Product supply chain.* Data on the supply chain that is collected will explain the product and information flow along with supporting data such as ordering data, shipping data, cost data, and others. The information flow begins when the product inventory at retailers is less than the amount requested by consumers. Retailers will place orders with distributors to meet consumer demand. After the order from the retailer is received by the distributor, the distributor will order the product to the factory. Orders to the factory are made when the distributor inventory is less than the amount requested by the retailer. Information flow in the form of the number of orders is influenced by the safety stock of each link. Safety stock is used to anticipate future requests. Whereas product flow is influenced by lead time, i.e. the time needed for the product to get to the next chain. Meanwhile, the product flow starts from the factory which sends the product to the distributor according to the distributor's order. When the product is received by the distributor, the distributor will send the product to the retailer according to the retailer's order. After the product is received by a retailer, consumer demand can be fulfilled.

Historical data about demand fulfillment activities can provide an overview of the real situation related to the current demand and supply conditions in the company. Based on data collected for 12 weeks, namely between January and March 2019, it was found that: at the retailer level it can be seen that sometimes consumer demand exceeds the inventory owned by retailers, but there are also times when retailer inventory exceeds consumer demand; then in the distribution level, where there is a time when inventory exceeds the order and vice versa often the distributor inventory is more stock than the order received. The inventory system will affect the costs incurred both storage costs, message costs, and backlog costs.

3.1.3. *Causal loop diagram.* There are two relationships in this diagram, namely positive and negative relationships. Both of these relationships are key to how a variable influences other variables. The information flow begins when the product inventory at retailers is less than the amount requested by consumers. Retailers will place orders with distributors to meet consumer demand. After the order from the retailer is received by the distributor, the distributor will order the product to the factory. Orders to the factory are made when the distributor inventory is less than the amount requested by the retailer. Information flow in the form of the number of orders is influenced by the safety stock of each link. In addition to the number of products shipped by the factory, the distributor's inventory is also affected by the lead time which shows how long it takes to get the product from the factory. The amount of distributor inventory will affect how much product is sent to retailers. The more products a distributor has, the more products are sent to retailers in accordance with the request to the distributor.

A backlog will occur when supplies cannot meet the demand either at the retailer or distributor level. Besides the lack of inventory, the backlog is also influenced by how long it takes to get the product from the factory. The longer it takes to get the product, the longer the demand cannot be fulfilled. When inventory is less than demand, inventory adjustments will be made. Inventory adjustments are activities carried out to adjust inventory with the number of incoming requests. B1 is a balancing loop (negative loop) which describes the more distributor inventory, the distributor inventory adjustment will decrease. That is because the demand from retailers can be fulfilled by the inventory available at the distributor so that there is no need for distributor adjustments. B2 is a balancing loop (negative loop) which describes the more inventory in a retailer, the inventory adjustment made will be increasingly reduced. That is because the end consumer demand can be met
by the existing inventory so that no adjustment is needed for the distributor. The more products that become backlogs at distributors, the more orders will be placed at the factory. This will add to the cost of messages that must be incurred. The same thing happens with backlog costs that will increase with the increase in backlogs at distributors. The distributor's storing costs will increase as inventory builds up which is influenced by the number of products received from the factory. Causal loop diagrams are shown in Figure 1.

![Causal loop diagram](image)

**Figure 1.** Causal loop diagram.

3.1.4. **Stock flow diagram.** Stock flow diagrams explain the flow of material and information based on causal loop diagrams that have been made. Diagrams for supply chain simulations illustrate the flow of information in the form of requests and products sent to meet these demands. The diagram is shown in Figure 2.

![Stock flow diagram](image)

**Figure 2.** Stock flow diagram of supply Chain.

Simulation of inventory system. Inventory model simulation is performed using licensed Powersim 10 with 3 scenarios, as follows: (a) real situation scenario: the simulation results show that the
distributor's inventory is greater than the retailer's inventory, with the safety stock, the backlog can be overcome because the incoming demand can be covered by the inventory that has been prepared previously (Figure 3); (b) raising the safety stock level scenario: this scenario to increase safety stock is carried out to reduce the level of backlog, the results of simulations indicate that when the safety stock is increased to three days, the backlog costs will be reduced because the backlog can be met by the available inventory, but the addition of the safety stock will affect the cost of storage because there is a lot of inventory prepared (Figure 4); (c) reducing lead time scenario: this scenario of reducing lead time is done to reduce distributor inventory levels, the simulation results show that when the lead time is longer, the product will get longer by retailers. In addition, the longer the inventory is in the distributor before it is sent to the retailer, the improvement made is to reduce the lead time from the original distributor for two days to one day (Figure 5).

![Figure 3](image1.png)
**Figure 3.** Stock and backlog condition at the real situation.

![Figure 4](image2.png)
**Figure 4.** Backlog and stock conditions before and after increasing inventory stock scenario.

![Figure 5](image3.png)
**Figure 5.** Backlog and stock conditions before and after increasing lead time scenario.

Cost is a parameter to determine which scenario is considered better. For this reason, the total cost between the initial conditions and the conditions after the scenario is calculated. The variables being compared are the value of inventory amount, amount of orders placed, and the number of backlogs that the distributor has borne for three months. The calculation results are shown in Table 1.


Tabel 1. Comparison costs between normal conditions and scenarios.

| Scenario                  | Amount of inventory (prod/3 month) | Amount of backlog (prod/3 month) | Total cost*) (Rp/3 month) |
|---------------------------|------------------------------------|----------------------------------|--------------------------|
| Normal                    | 34839                              | 1241                             | IDR 242,696,984          |
| Raising safety stock      | 60354                              | 200                              | IDR 414,210,146          |
| Reducing lead time        | 32910                              | 1015                             | IDR 228,817,885          |

*) Inventory cost + order cost + backlog cost

4. Conclusion

One effort that the industry can do to be able to compete in this increasingly competitive situation is to make companies more efficient where one of them is through improving supply chain opportunities and inventory systems. The relationship between inventory system variables in PT. Tri Sapta Jaya, which is depicted using a dynamic modeling system approach through causal loop diagrams, can describe positive and negative relationships between variables, which means that one variable influences the other variables to create a causal loop. The depiction of a stock & flow diagram can explain the causal relationship that has been described quantitatively. Changes to one variable can affect other variables because they are in a series. After simulating with Acknowledgments scenarios, the best scenario to minimize the total cost of savings is to reduce lead time.

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References

[1] Sarimveis H, Patrinos P, Tarantilis C D and Kiranoudis C T 2008 Dynamic modeling and control of supply chain systems: A review Computers & Operations Research 35(11) 3530-3561
[2] Yusuf Y Y, Gunasekaran A, Musa A, Dauda M, El-Berishly N M and Cang S 2014 A relational study of supply chain agility, competitiveness and business performance in the oil and gas industry International Journal of Production Economics 147 531-543
[3] Sanders N R 2011 Supply chain management: A global perspective (Wiley Global Education)
[4] Park K and Kyung G 2014 Optimization of total inventory cost and order fill rate in a supply chain using PSO The International Journal of Advanced Manufacturing Technology 70(9-12) 1533-1541
[5] Wang X and Disney S M 2016 The bullwhip effect: Progress, trends and directions European Journal of Operational Research 250(3) 691-701
[6] Pujawan I N and Mahendrawathi E 2017 Supply Chain Management (Andi Publisher)
[7] Misni F and Lee L S 2017 A review on strategic, tactical and operational decision planning in reverse logistics of green supply chain network design Journal of Computer and Communications 5(8), 83-104
[8] Habib M 2014 Supply Chain Management (SCM): Its Future Implications Open Journal of Social Sciences 2(09) 238
[9] Gunawan A 2007 Analisis Perbaikan Rantai Pasok (Supply Chain) Menggunakan Sistem Dinamis (Studi Kasus di PT. Jauwannah Traco, Yogyakarta) UII
[10] Caponio G, Massaro V, Mossa G and Mummino G 2015 Strategic energy planning of residential buildings in a smart city: a system dynamics approach International Journal of Engineering Business Management 7 20
[11] Disney S M and Towill D R 2002 A procedure for the optimization of the dynamic response of a vendor managed inventory system Computers & industrial engineering 43(1-2) 27-58
[12] Prahasta E 2018 Systems Thinking & Pemodelan Sistem Dinamis (Jakarta: UPT Perpustakaan STMIK Handayani)