

Inventory Management Optimization Model with Database Synchronization through Internet Network (A Simulation Study)

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Abstract— In the past (classical supply chain) the supply of goods generally flow starts from factory or producer, then producer sent to a storage area called the warehouse. When finished goods are collected, the goods from storage area or warehouse (WH) is distributed to the distribution center (DC). Then after the goods were placed in the Distribution center, then the goods are shipped to the retailer (retailer). The drawback of this system is when there is a shortage of goods at the retail level, it takes a long time in the distribution of goods, from warehouse into the retailer. With the approach of the Physical Internet (PI), where the objective is to combine into a unified logistics network, the system is inter connected, the inventory can be shared through hubs that serve the market and distribution of resources. In other way, the function of warehouse and distribution center was replaced by hubs that serve to optimize transport and inventory. Although the physical internet inventory control model better than the classical model, but the model of inventory management with database synchronization better than the physical Internet. With the approach database synchronization, several hubs can be combined into one hubs, and the plant can also sending goods directly to the retailer. In addition to optimizing transport and inventory, this analysis allows to choose a dynamic source when an order is placed: source substitution. Although this calculation is working on a computer simulation, the main intent of this paper is to define new research model inventory controlling better than classical inventory model and physical internet inventory model, which is inventory management model in synchronized database.

Keywords—inventory control with synchronized database, synchronized database inventory model, optimization synchronized database inventory, replenishment with synchronized database

I. INTRODUCTION

Inventory management is a crucial aspect in a factory or a company, particularly in the sector of Fast Moving Consumer Goods (FMCG). The absence of an effective inventory management of the company will lead to inventory wasting, even time and cost loss, and warehouse inefficiency [1]. A good company tends to develop a good time and cost management, as well as inventory control. When a company is able to control supply chain and satisfy customers' demand, customers tend to make a purchase in the company, and therefore, circulation of company's sales turnover will increase. The increase is required by a company to grow its business and to expand its capacity. The goals that become the prior duties of a company include meeting customers' needs and reducing inventory-holding cost along with other costs. As

defined above, everything begins from customer satisfaction on the demand of purchased needs. Common problems which arise include terrible service, product availability which is not needed or sought by consumers, excessive stocks in warehouse, a large number of stalled goods unsold in a long period of time, stock shortage, and the absence of reference on quantity ordered. There are still many more factors for the purpose of meeting customer satisfaction on fulfillment of purchased goods which are not mentioned in this paper. However, in order to make a more-centralized inventory management model, this research focuses on time and quantity of requested goods. Before discussing this problem, it is better for us to recognize the cycle of FCMG inventory management from previous studies toward its real practices, such as centralization of inventory, as stated in [2] and [3], Vendor Managed Inventory (VMI) in [4] and [5], Collaborative, Planning, Forecasting and Replenishment (CPFR) in [6] and [7]. Based on the above literature reviews, we notice the types of inventory management model examined in previous studies in order to increase fulfillment of goods. In addition, there exist several researches on commodity supply chain based on types of goods using Physical Internet model (PI), which have been discussed in science magazines, books, as well as in [10]. According to the aforementioned researches, the concept of Physical Internet is how to inter-connect various independent computer networks. That is to say, the main purposes of PI are to connect various independent logistics networks and to make use of those networks to be open logistics networks for sustainable development. This concept implies that a company will utilize similar facilities to distribute goods by boat, car as well as by other means of transportation. Some researches focus on predominance of transportation including its efficiency in the sector of FMCG in [11] and [12]. We will discuss inventory management model with Synchronized Database (SD) further, in which data collection is centralized (replication of each retailer's database to central company's server). The data which have been collected in the central database are processed to create lists of depleted goods and details of quantity needed by each retail location. Furthermore, the lists are delivered to a factory through internet network in the form of softcopy. As soon as a supplier receives copy of the picking list from the factory, distribution will be scheduled (by a heavy duty trucks or several heavy duty trucks) to each retailer which has same direction to the destination point. This concept is called inventory management model with SD.

General explanation on database replication or synchronized database can be seen in [13]. More detailed explanation shows that retailer's database is connected to internet network and the data then are drawn and collected by central server. Next, these collected data are processed and analyzed. In case that one or some retails undergo stock shortage, central computer will arrange picking list as well as the quantity needed by each retail location. This synchronization is commonly conducted in the dawn when data can be freely accessed. Once the data are received by supplier, goods needed by retailer will be distributed and gradually dropped to retail location based on list of stock shortage arranged by central computer. In reference to aforementioned explanation, several improvements are made with the concept of PI model. This model connects suppliers to hub, one hub to another hub, and another hub to retailers. Besides, it prohibits direct distribution from suppliers to retailers without passing through hubs. Meanwhile in SD model, central database collects all data of retailers' database and then counts the demand of depleted goods requested by each retail location and finally distributes directly from suppliers to retailers to replenish at stores.

This paper discusses a research on development of better inventory management model and reduction of operating expense. Some research questions examined in this paper are: (1) What is the difference between PI and SD in term of inventory management procedures? What are their benefits? (2) What is the difference between PI and SD? (3) In what case can SD be developed to be a new inventory management model and how does it work? The most important thing to underline is that the main goal of this paper is not to conclude the best inventory management model in SD, but to provide alternatives of benefits which are obtained when using the concept of this model.

II. SCHEME OF REPLENISHMENT IN SYNCHRONIZED DATABASE

This section examines impacts of hierarchical transformation from classical distribution network to PI and to SD respectively. We use three types of inventory distribution network models presented in Figure 1, Figure 2 and Figure 3.

Figure 1 indicates a classical inventory system in which two suppliers (producers) produce two different products and each of them possesses a plant and a warehouse (WH). Each warehouse fills in a group of Distribution Centre (DC) in an area representing retailers. Each DC replenishes stock to a group of Point of Sale (POS) in which point of sale of costumers' demand is fulfilled. With this hierarchical tree structure, stock movement among stock points on similar or perpendicular echelon from retailers to warehouses is commonly not allowed in FMCG supply chain. On the basis of this structure, significant and appropriate purchasing decision of depleted goods with certain required quantities is necessitated by considering various problems such as complexity of service and high operating expense.

Figure 2 provides an example of inventory management model which differs from PI. In this scenario, network is connected to standardized interfaces. Stocks of goods are

packaged and kept in a standardized container called PI completed with a sensor filled with such relevant information as destination route. With PI container, stocks of goods from suppliers are stored in hubs (also called PI hubs in Physical Internet) and this open network can be accessed by all users. Suppliers (manufacturers) are free to input their products in one of the hubs and therefore they can both push product sales and monitor the level of product availability in the hub. The advantages of this model are: (1) products can be distributed freely from a supplier to a hub and a hub to another hub which has a high demand of products, (2) retailers (PoS) can create a demand of product supply from a hub located nearby the supplier and surely with sufficient supply to replenish depleted stocks of goods, (3) distribution of goods can be tracked, (4) safety is guaranteed.

Figure 3 provides an insight of transformation change namely new model of inventory management using SD (Synchronized Database). This model enables several hubs to be merged into a hub and this hub distributes goods to a retailer which we call PoS. Everyday central hub collects data information from all retailers included as subsidiaries. Next, the central hub counts and analyses stock shortage and makes picking list. This list is sent to supplier and then the supplier receives data from central hub and prepares for production. After being produced, the products are distributed to retail location which undergoes stock shortage based on the list made by central computer. This concept mostly resembles PI, but the hub represents central hub of all retailers' database. With this inventory management model, (1) the products can be distributed freely, (2) fulfillment of stock needs will be guaranteed, (3) suppliers will easily monitor stock shortage and flow of goods, (4) retailers can save lead time, and (5) safety of products which are distributed is guaranteed.

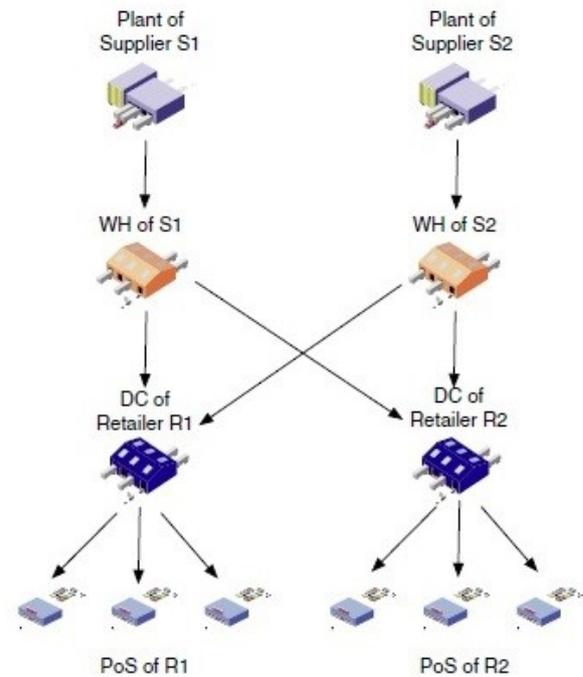


Figure 1. Traditional FMCG Distribution Network

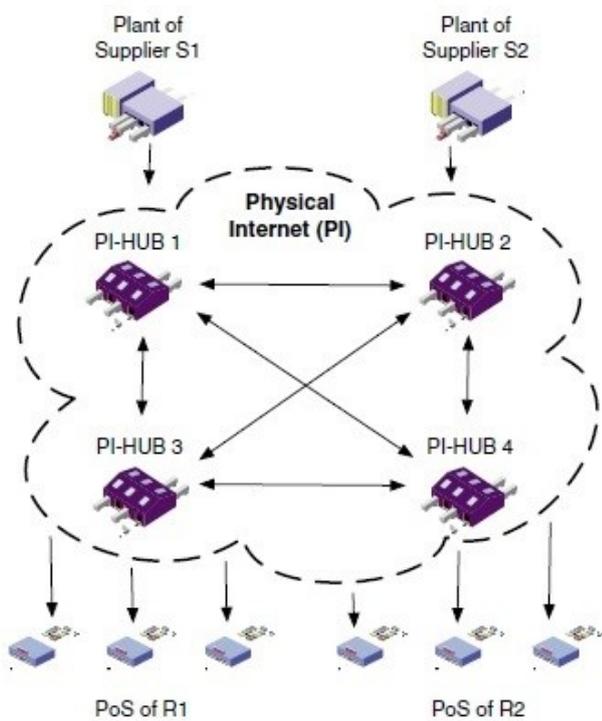


Figure 2. Open Distribution Network through Physical Internet

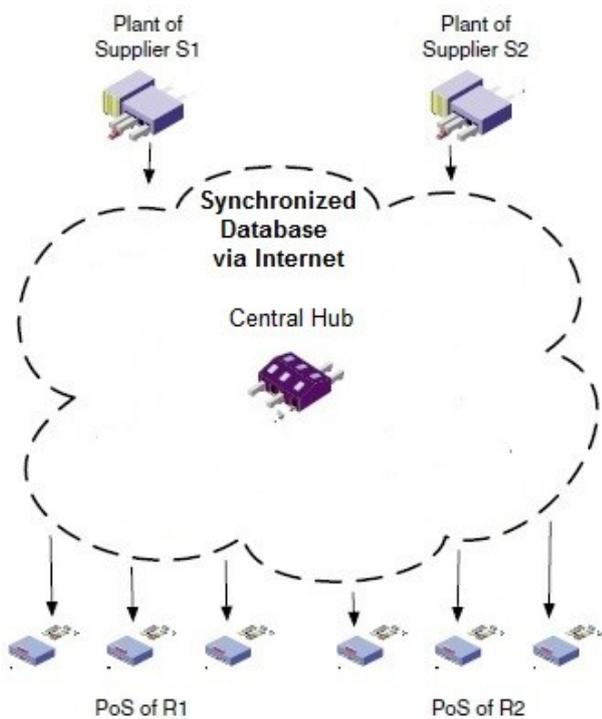


Figure 3. Synchronized Database through Internet Network

III. DEFINING RULES FOR PRODUCT REPLENISHMENT IN SYNCHRONIZED DATABASE

This chapter aims to explain several inventory models in Synchronized Database (SD). Based on three benefits of SD features, like direct shipment from suppliers (by organizing picking list), many suppliers have more flexible distribution points. This leads to three decision variables: economic order quantity, lot size for each retailer, and direct distribution point from supplier or hub. We ensure rules of replenishment in SD under (Q, R) inventory policies and consider the absence of backlog.

3.1. PI Supply Network

In PI network, every order can be satisfied by different sources points according to the current real-time status and the criteria of selection. However, manufacturer should not directly deliver goods through nearest hub or hub whose product availability meets retailers' needs. For instance, order requested by retailer 1 can be shipped from all hubs, and a hub with a shortage in a stock can directly make an order to supplier depending on the criteria of selection. There are two key factors to be considered, comprising distance between source and destination points (desired location) and level of product availability in sources points

3.2. Alternative strategies in the SD

In SD model, each picking list can also be filled by different source points according to the current real-time status and the criteria of selection, and products can be directly carried out by supplier to retail location. The difference between PI and SD lies on the data center which already notices the product availability in each retailer (automatically) from daily data synchronization. This is done by central server. For example, stock shortage in retailer 1 can be replenished by supplier or hub depending on the criteria of selection (picking list automatically made by central server). The most important thing to consider is the distance between source point and product availability.

IV. RESEARCH SIMULATION AND RESEARCH FINDINGS

4.1. Costing

Information about cost is communicated with research partners. As explained above, there are only two key elements taken into account in this research: inventory and transportation. Generally, holding cost model is linear, serving as function of the storage duration of volume measured by a cubic meter (m³). The holding cost is measured by using the following formula:

$$\text{Holding cost} = \text{volume (m}^3\text{)} * \text{day} * a \text{ (\$/day m}^3\text{)}$$

In short, the holding cost model in warehouse or hub is USD 0.11 / (day m³), while at the retailer, the cost is given by a 3/2 ratio, which is equal to USD 0.165/(day m³) since holding cost in retail shops is higher. Transportation cost is the only variable taken into account in this research model, and it is accumulated for each truck. The cost for using a truck, without considering whether it is fully loaded or not, includes the fixed

cost and the variable cost in function of the consequence of longer road distance. The transportation cost per truck is measured by using the following formula:

$$\text{Transportation cost per truck} = f + \text{km} * \$1.4/\text{km}$$

The model for cost function used is transportation of fully-loaded truck, which is commonly used in the case of FMCG product replenishment.

4.2. Simulation models

To test the different strategies defined above, we develop a model in Anylogic which is a multi-method simulation modeling software developed by XJ Technologies (www.anylogic.com). This multi-agent program is run on the basis of simulation model [14]. Without providing details of this model, this section presents the calculation of feature and assumption for simulation models to help readers master the operation of the models as follow:

1. Model of discrete event simulation;
2. Time of simulation is 1000 days (all the order processes take place once a day). Nevertheless, to wipe off the impact of the initial inventory level on the result, only the 730 days (two years) in-between the period are used for data analysis;
3. Daily demand submits to Normal distribution (mean values and standard deviation values are defined and presented in Table1);
4. Network pattern is fixed (number of plants, WHs, DCs, Retailers and hub, as well as their location, distance and lead time);
5. Simulation is driven by the minimization of the total cost of the supply network (transportation cost plus inventory holding cost);
6. Experiment designed to minimize the total cost according to the inventory parameters of Lot size (Q) and Reorder point (ROP) and to determine the coefficient which were defined in the replenishment criteria;
7. Unmet demands are considered as lost sales and they are not considered as part of the total cost;
8. Direct shipments from the plant to retailers are allowed, and;
9. All plants are considered as unlimited production sources (without regard to inventory cost and production cost).

4.2.1. Scenarios of PI network

Scenarios of PI network is described as in figure 4, in which supplier (producer) can replenish products for hub 1 to hub 3, and r1 can be replenished with products by hub 1 to hub 3. This means that request for product replenishment can be accommodated by hub nearby the retailer, and therefore, the replenishment can be satisfied. By employing PI network model, replenishment can be carried out without simply passing through several locations, like warehouses.

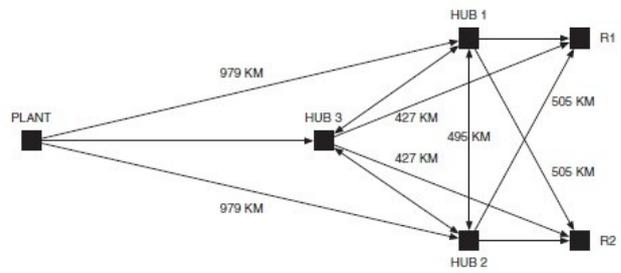


Figure 4. Physical Internet Supply Network Design for Simulation

To measure the cost, we need to calculate mean value and standard deviation of daily demand, lead time, and lot size. Those variables are essential to input data for simulation. The unit of product is measured in full pallet (e.g. 1.73 m³). Parameters are displayed in Table 1. Parameters 1 to 9 are fixed in all scenarios of simulation since the aforementioned data are related to the demand at retailer level and the network pattern.

Table1. Parameters of Experimental Simulation of PI Network Model

No	Parameters	Unit	Type	Value	Step
1	Daily Demand R1	Units/day	Stochastic	Mean = 20, S.D = 4	-
2	Daily Demand R2	Units/day	Stochastic	Mean = 35, S.D = 7	-
3	Lead Time HUB to R	Days	Fixed	7	
4	Lead Time HUB to Hub	Days	Fixed	10	
5	Lead Time Plan to Hub	Days	Fixed	14	
5	Lot Size Retailer 1	Units	Fixed	76	
6	Lot Size Retailer 2	Units	Fixed	90	
7	ROP Retailer 1	Units	Fixed	27	
8	ROP Retailer 2	Units	Fixed	47	
9	Lot Size Hub to Hub	Units	Discrete	20-800	20
10	Lot Size Plant to Hub	Units	Discrete	20-1000	20
11	ROP HUB1	Units	Discrete	20-800	10
12	ROP HUB2	Units	Discrete	20-800	10
13	ROP HUB3	Units	Discrete	20-800	10
14	Production Lot to Plant	Units	Fixed	1200	-

4.2.2. Scenarios of SD

Compared to figure 4, it is found that product supply pattern in SD is almost the same as that in PI network. As hubs 1, 2, and 3 are merged into one, the complexity of shipment becomes simpler and lead time of a truck is shorter. Since data are synchronized through central database, the distribution channel cuts public channel, as occurring in PI network model. Road distance between source point and ordering point, hence, becomes shorter.

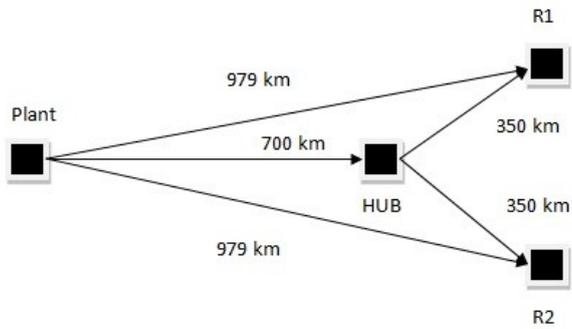


Figure 5. Synchronized Database Supply Network Used in Simulation

As defined above, parameter 3 in SD is substituted by parameter 4 as a consequence of product channel simplification. Parameters 9, 12, and 13 are not required in inventory model through SD, while the other parameters in PI are still utilized in inventory management model through SD, as presented in figure 2. Similarly, optimum value will be acquired by running simulation program.

Table 2. Parameter of Experimental Simulation of SD Model

No	Parameters	Unit	Type	Value	Step
1	Daily Demand R1	Units/day	Stochastic	Mean = 20, S.D = 4	-
2	Daily Demand R2	Units/day	Stochastic	Mean = 35, S.D = 7	-
3	Lead Time HUB to R	Days	Fixed	10	
4	Lead Time Plant to Hub	Days	Fixed	14	
5	Lot Size Retailer 1	Units	Fixed	76	
6	Lot Size Retailer 2	Units	Fixed	90	
7	ROP Retailer 1	Units	Fixed	27	
8	ROP Retailer 2	Units	Fixed	47	
9	Lot Size Plant to Hub	Units	Discrete	20-1000	20
10	ROP HUB1	Units	Discrete	20-800	10
11	Production Lot to Plant	Units	Fixed	1200	-

V . CONCLUSION

This paper provides insight on a new research question on inventory management in specific context: Synchronized Database. This question is considered new in this field since Synchronized Database allows some important new flexibilities that are, in fact, not always worthy and suitable for current classic supply chain. Products can be possibly distributed by suppliers to retailers either with or without hub, by using internet network. Several alternatives are provided by suppliers, which mean that demands can be divided, and then filled by more than one source points. Dynamic reduction of inventory is carried out on the basis of variations in market demands. The result shows that SD model causes holding cost to decrease, as well as, reduces total cost of logistics, when

terms and conditions of the model are met. This paper does not aim at providing a conclusion on the best inventory management model and practice of SD simulation model, but it is more likely to provide basic illustration of the performance improvement with other ways/criteria in implementing open logistic network.

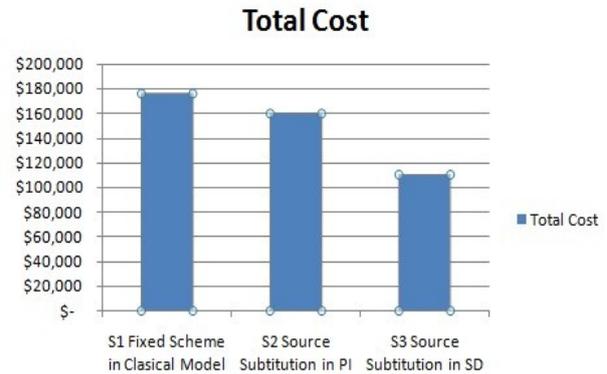


Figure 6. Total Cost of Simulation Scenario

There are several limitations in this research. First, the results are optimum; however, the research is limited to the network/group organizations, parameters, rules, and obstacles encountered. Further research and experiment are required to find out the obstacles and significance of the criteria and the performance of organization chain of SD model versus PI model. Secondly, the simulation model contains only the basic cost of logistics and inventory holding cost and customer service variable. Some critical factors need to be considered in further research, for example, programmer salary, employee salary, operating cost, and safe stock level. In the earlier discussion, this paper explained other studies on inventory management through Physical Internet. A number of relevant studies discuss a topic on SD, for instance, a topic dealing with the first question, namely the potential effect of PI on Bullwhip effect. On the other hand, SD potentially changes the organization, from decentralized to centralized [15]. In other words, this model occasionally makes more direct and shorter distribution route than that of classical hierarchical distribution model. The Inventory-Routing Problem [16] can also become an interesting question in SD. Finding and developing more effective and efficient transportation systems are the main aspects, and the main purpose of inventory model in SD is to maximize inventory level that must be ordered when worthy and guaranteed transportation is provided. It can be acquired from other literature, that is, the aspect of the Inventory-Routing Problem.

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