International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Study on the Criticism of the Safety Stock in Supply Chain Environment

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Abstract

Supply chain optimization is playing a great role for organizations to face high dynamic environment. One of the most important parts in optimization is inventory optimization which can obtained by optimize the safety stock based on the balance between holding cost of safety stock quantities and shortage cost of unfulfilled of customer demand. Fuzzy logic system considered adoptable tool can deals with uncertainty and dynamic environment and it can assemble and control demand and supply variability to identify optimal safety stock level by using same resources. A major limitation in safety stock researches is the rare of the researches that deals dynamically with inventory and employing daily basis calculation; hence the aim of this research is to provide comprehensive study about safety stock and its approaches as well as the trends of future work in this field.

Keywords: Supply Chain; Safety Stock; Stochastic Service Approach; Optimization.

1. Introduction

Optimization of supply chain inventory considered top preference to the executive as shown by study of 153 executive managers which was conducted in research study in 2013 [1].

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Despite the many researches that had been written in the inventory management, the problem of identifying the optimal level of inventory remains one of the most important problems facing the manufacturing environment. Therefore, it is significant to identify scientific approaches which enable companies of determining the level of safety stock and meet with customer demands based on reducing total cost. The research in the inventory field generally has one of two scenarios to deal with stock-out problem, either the customer choose alternative market to fulfilled its need, or he wait until the product is available, the leave off purchasing will lead to loss of company profit while the latter known as backorder. In practical situation, when demand unfulfilled occur, usually the customer will refuse to waiting backorder [2]. This is assisted by Y.-J. Lin (2013) where they found that 15% of the customer can delay the purchase of a particular product when the stock-out occur, while 85% of customers distributed among either buying another product, buying the product from another source, or leave buy of this product product [3]. As a result, the use of safety stock becomes an important part of the supply chain to avoid this type of risk [4]. The amount of raw material provided by supplier is an important element in determining the amount of safety stock, so stochastic service approach considered suitable to applied in real system because it deal with concept of risk may appear according to different uncertainties included delay in providing of raw material [5]. Customer demand variation and manufacturing expose to disruption form great challenge face the organization if the mount of safety stock not identified correctly and scientifically. The optimal level of safety stock must be identified and involved in all nodes of supply chain to meet with pre-specific service level and verify customer satisfaction. Exist of safety stock in supply chain members will allow the managers of organization to deal with demand fluctuation in downstream and supply in upstream. The importance of having safety stock was distinguished by Hany Osman 2012 where he was define a set of reasons drive company fail to achieve customer needs, one of those reasons is not to employ the concept of safety stock properly [6]. Inventory of organization represent a major defense line to face disruption in demand. For the supply chain that facing uncertainty in demand and supply, inventory system considered great challenge, so it is very important to calculate optimal amount of safety stock to absorb potential impact of failure to meet the customer demand[7]. In spite of the importance disruption management in supply chain and their impact on competition, there is little research about impact of supply chain disruption management [8] . Generally, supply chain consist of multi-stock points and these points used to store raw material and products and each point is subjected to variation in demand and supply, so the level of safety stock must identify accurately in order to find all parameters related to inventory system and identify the optimal level of raw material and finished product at each member of supply chain. The process of inventory management considered one of the most important research topics in the recent periods and takes a wide range of researches area due to its direct impact on the total cost of organization and as results the performance of this firms [9]. Minimizing of total cost and verify customer satisfaction considered main aims of supply chain, both of these two goals are related to inventory level , so the optimization of this level and identify the safety stock based on pre-specific service level is the main goal of different researches [10].

2. Approaches to Safety Stock

Generally, there are two approaches used to identify safety stock level, guaranteed service approach (GSA) and stochastic service approach (SSA). The first approach (GSA) presented first time by Simpson 1958 while the second approach (SSA) presented by Clark and Scarf (1960) for dealing with uncertainty [11]. Based on guaranteed service approach (GSA), safety stock and operating flexibility such as increasing production rate or added working shift used to dealing with uncertainty in supply chain against demand uncertainty. The main principle of (GSA) is the service time between upstream and downstream must be set and then identify appropriate safety stock level to achieve their commitment[7]. For stochastic service approach (SSA) the safety stock calculated to protect against uncertainty in demand and supply. The difficulty of (GSA) is in identifying maximum level of safety stock which represents a requirement of internal service level lead to extraordinary resources. Hence the service level in GSA is considered as a parameter and not variable[12].

Therefore, by identifying internal service level, safety stock level can be calculated by [12]

$$SS = k * \sigma\sqrt{lt} \quad \ldots\ldots 1$$

Where:- $SS, safety\ stock\ level;\ k, service\ level\ factor;\ lt, lead\ time$

In stochastic service approach (SSA), safety stock level is only the way used by organization against disruption in demand, so the service time of each stock point is effected and not guaranteed to deliver the product to customer. When stock-out occurs the customer must wait until the raw material is arrived from external supplier [11]. The comparison between the two approaches is highlighted in table (1) with referencing to the research practitioner for each component of comparison

Table 1: Comparison between (SSA&GSA)

Parameter of comparison	Guaranteed service approach(GSA)	Stochastic service approach (SSA)	References
Service level	Input parameter	Input variable	[1], [2]
Uncertainty source	Demand uncertainty only	Upstream and downstream uncertainty	[1], [2], [3]
Stock-out occurrence	When stock-out occurred, the node of	When stock-out occurred, the customer must wait until raw	[4], [1], [5]
Demand level	Demand level identified and bounded in order to	Demand level is not limited	[6]

3. Controlling safety stock level under uncertain environment

Generally, there are two models used to adjust the safety stock level in supply chain, these are:-

- **First point**. common statistical models for adjusting safety stock level based on two assumptions:-

1. Deterministic lead time and randomness in demand which is working under fixed lead time, so safety stock (SS) is calculated by [7]:

$$SS= K * \sigma * \sqrt{LT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where k is a service factor corresponding to service level, σ demand standard deviation, and LT is referring to lead time

2. Randomness in lead time and demand is presented, and according to this case, (SS) can be adjusted by[8]

$$SS= K * \sqrt{{\sigma_d}^2 * LT + \mu L^2\ {\sigma_L}^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where k is a service factor, σ_d demand standard deviation, LT lead time, and σ_L lead time standard deviation, and μL^2 is square of average lead time

Moreover, from the equations (1&2), lead time which is represented by the total time from release order until receive the product still a component which need to be defined precisely. It calculated by following equation (3);

$$LT = Tm + Tmo + Tci – Tco \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Each area of supply chain includes three control processing parameters, inbound service time (Tci), process time (Tmo), and outbound service time (Tco). Input time represents the guaranteed time to be received by a specific area, processing time is referring to time consumed in all process made in specific zone, and output time is a guaranteed service time needed to send out of product for downstream stage of supply chain. Transportation time (Tm) will added for each procedure of transportation between upstream and downstream zone.

It is obvious from equation (3) there is an important constraint related to the components of time (Tmo, ,Tci, andTco) that the outbound service time of downstream (Tco) should be equal or less than summation of upstream time plus transportation time i.e (summation of Tm, Tmo, and Tci). <u>It is restricted by the outbound service time (Tco) should be within:</u>

$$0 \leq Tco \leq Tm + Tmo + Tci \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Because the distribution centers (DC) can receive products from different manufacturer and in order to ensure products arrive at the specified time, the suitable time to receive the products by distribution centers is the maximum summation of processing time and transportation time of the manufacturer units as shown in equation (4)

$$T_{cij} = max\{T_{moij} + T_{mij}\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

T_{moij} Guaranteed service time needed by product (i) to arrive to downstream (j)

T_{mij} Transportation time needed by product (i) to arrive to downstream (DC) (j)

Safety stock (SS) is related to three variables; customer service level, demand uncertainty, and lead time uncertainty. Many researches applied this approach to calculate (SS). [H. Osman and K. Demirli 2012] developed model of safety stock in multi-echelon supply chain based on uncertainty in demand and lead time. Two models for the calculation of the safety stocks. They discussed decentralization model used to obtain the (SS) at each stock point of supply chain, while the second model of approach employed consolidation concept by which a specific centers was determined to have suitable level of (SS). The results showed that the second model was more efficient and provided a distinct results by reduction of safety stock amount ranging in (45.2–62%) as well as cost saving by a range (22.2–44.2%) in compared with first model application [9], **[**An optimization and simulation model aws presented by B. Amirjabbari and N. Bhuiyan (2014) to identify safety stock placement and allocation based on minimizing logistic cost and to identify performance measurements respectively. The location and allocation of safety stock was dealt by optimization model employing Lingo programming, nonlinear model is explored to minimize safety stock cost. The optimization make interrelated between amounts of product in downstream to save lead time and amount in upstream to save holding cost. While simulation was used to calculate the performance of supply chain based on five metrics identified which are on time delivery, first fill rate, length of lateness, safety stock coverage, and quality report information The simulation model results supports the result of the first model i.e. optimization model for the optimal safety stock allocation and location [10]. [S. Sharma and A. Malhotra2015] presented a model to optimize inventory and also to set safety stock level in fast move consuming goods, major attention on the parameters which impact safety stock with normal demand distribution, the results are highlighted the reducing in inventory cover days from 35 to 28 day and reduction in holding cost reach up 20% [11]. E. Hernández and his colleagues 2016 developed an approach to identify and reduce level of safety stock for modular product; group technology was the commonality concept in approach through a ssubstitutability factor. According to the results of applied this model, the safety stock levels is reduced between (48.1-27)% [12].

- **Second point** The second approach to adjust safety stock level is concentrated on artificial intelligence computation. These approaches differ from traditional approach as the employing of expert knowledge to describe the variables in linguistic terms, and then logical rules are developed in order to extract fuzzy inventory values. Tanthatemee (2012) developed fuzzy logic control system to optimize inventory level, through two inputs and two outputs. Input parameters were demand uncertainty and supply availability while output parameters were order quantity and reorder point. The researcher concluded that the advanced approach is more flexible to modify and readjust the parameters when needed in addition to the reduction in the total cost within (81.55-96.02) [13]. [H. R. Rezaei 2013] used fuzzy logic theory to identify supply chain safety stock; a **weighted association rule** is used to determine the weights of variables instead of the equally importance (i.e. with the same weight) in order to obtain higher accuracy results. There are three input variables which are Weighted- Fast Slow-Non moving, weighted cost, and lead time, all of these variables used Gaussian membership function while one output i.e. safety stock with triangular membership function[14]

4. Review and summary of related researches:-

The first study that integrated the inventory in a multi-part supply chain was published in 2010 by the researcher Grossmann[7]

4.1 Criticism guaranteed service approach (GSA)

[Graves 2008] proposed model to identify safety stock place in supply chain by extension from stationary demand to the instability demand as that occur with short product life cycle, where they develop Graves-Wiiliam (G-W) model to identify appropriate position of safety stock, the purpose is to present high service level in accordance with minimum cost.

Lead time randomness in SS of the research of Salal Humair **(2013),** he developed model to optimize inventory in supply chain and identify safety stock based on assumption of guaranteed service approach (GSA). The calculation of safety stock level and location which used in different industries made based on deterministic lead time, they also generalized guaranteed service with constant lead time (GS-DLT) into generalized guaranteed service with random lead time (GS-RAN) in order to inclusion the lead time randomness in any stage of supply chain, after comparison with heuristic models, (GS-RAN) model presents more accurate safety stock values and also provides optimal stages to have safety stock in entire supply chain [15].

Extension of guaranteed service approach to include date based demand is provided by Kenichi Funaki (2012) which aims to solve problem of safety stock placement. The model of safety stock placement is incorporated to the problem of network design and the optimization procedures are provided [16].

[Hany Osman 2014] deal with guaranteed service approach to identify safety stock, multi objective function used to minimizing total cost, high service level, and minimizing delivery time, the author also employed modified fuzzy Chebyshev program (MFCP) in order to solve multi-objective function. Their tool (MFCP) characteristic by its ability to deals with different objective according to their importance but the drawbacks in this research is that the time of manufacturing and the time of transfer materials which defined precisely but in real life the manufacturing process and the transfer process is affected by a range of randomness or fuzziness which is far away from being specific. [4]

4.2 Criticism stochastic safety stock

The study of ability to carrying safety stock at each location in supply chain when they have different holding cost was presented by **walid w. Naser** (2012), the goal of study is to minimizing overall cost at these locations. Sometime the optimal conditions requires transshipment of safety stock from one location to another, so this problem was solved by the model where the optimal amount of safety stock at each location and transshipment quantities were identified. Optimization is highly depending on disruption probability distribution and cost, high variation in disruption time will lead to increasing the overall cost and smaller amount of transshipment. The researcher build convex objective function contains three variables which are amount of safety stock at each location (two location in case study) and transshipment amount from one location to another one. By this function its become more accurate and efficacy in identify optimal conditions [17].

A fuzzy logic continuous control inventory management system for a single product is proposed by Tanthatemee **(2012)**, this model used to calculate reorder point and order quantity, where the proposed model deals with the uncertainty of the demand and supply. Using the linguistic expressions in the input and output characterization as well as the extraction of the inference rules from the historical data by the experts, the researcher can construct a model that can identify the optimal reorder point [18].

After applying the model to five sets of historical data and comparing it with the traditional model it turns out that the proposed fuzzy model is better by extremely saving the total holding cost and disappear of any shortage during the application. We note at the end of the research that the researcher pointed to the possibility of changing system parameters by using fuzzy logic when the conditions have been changed and it was noted as a future work.

4.3 Criticism of Hybrid method

Integration of stochastic service model (SSM) and guaranteed service model (GSM) to build new approach for the calculation of safety stock provided by klosterhatfen (2013). The researcher divides the supply chain into sub-strings of (SSM) and (GSM). Approach derives a cost-optimal partitioning of the supplychain into SSM and GSM sub networks and calculates the optimal base-stock levels. Through the application of the proposed model (HS) it became clear that its in addition to being better than both working purely in either of the two previous ways (i.e (SSM) and (GSM), the results are additional cost reduction amount approach to 3.6% at most and with mean 0.4%. . But there is a limit this research is the unconstraint capacity of all supply chain stages, hence the incorporation of capacity constraints will lead to more accurate results, [19] . The table (2) below presents summary about some related researches.

Table 2: summary of safety stock calculation approaches

No.	Author	Ref.	Year	Modeling	Simulation	optimization	Environment of application	Used tool	
								Fuzzy	Statistical
1	H. R. Rezaei	[14]	2010		✓	✓	SSA&GSA	✓	
2	W. W. Nasr et al..	[17]	2012	✓		✓	SSA		✓
3	Kenichi Funaki	[16]	2012		✓	✓	GSA		✓
4	S. T. Klosterhalfen	[19]	2013			✓	Integrated SSA & GSA		✓
5	Abdullah Yahia M	[4]	2014	✓		✓	GSA		✓
6	N. Grace Hua,& Sean	[3]	2015	✓		✓	GSA		✓

5. Conclusion

This paper focused on the importance of safety stock in global competitive environment. The research indicated preference for advanced approaches (artificial intelligence) on traditional methods because of different reasons such as:-

- One of great drawbacks in calculation safety stock in statistical approaches/models is the extreme in estimation of required quantity, which reflects the weakness of used model. The using of fuzzy logic to identify safety stock lead to reduction in safety stock quantity approach to 95% [18].
- Mathematical structure of fuzzy logic enable it to take the impact of different cases simultaneously because it represents the sets (variables and parameters) in specific percentages represents its belonging to the fact and this is not possible when apply mathematical calculations.
- The control of the safety stock is an effective factor in raising efficiency of organization and entering the competition for survival, which need effort when using the safety stock as a manufacturing perspective and this is more evident when using advanced computational approaches.
- Ability to readjust and modify of universe discourse of variables easily and this helps greatly in making decisions in a dynamic competitive environment when applying adaptive fuzzy logic and it is not possible when statistical equations are applied in the calculation of safety stocks [18].
- Advanced computational approaches give more flexibility to deal with variables and parameters in ambiguity environment and lack of data in addition to the employing of experts knowledge to identify safety stock level is properly manner.

6. Recommendations

By looking at the researches presented in the paper we can draw the following areas to develop in future:-

- Develop fuzzy logic system can handle demand and supply variation dynamically to identify appropriate level of safety stock.
- Inventory optimization by using optimization software in order to reduce the excess in storage.

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