A study of factors affecting supply chain performance

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Abstract. In the present global market, the competition is not between the companies but between the supply chains. The comparison of performance measures of supply chains helps to identify a good supply chain. The best performing supply chains may survive over a long period. The performance of a supply chain is affected by various internal and external factors. The objective of this paper is to identify and conduct a detailed study of the major factors affecting the supply chain performance. The factors are identified by reviewing various literature in the supply chain field. In this respect, a total of 54 literature are reviewed. The major factors identified as supply chain structure, inventory control policy, information sharing, customer demand, forecasting method, lead time and review period length. The optimum selection of parameters of these factors improves the supply chain performance.

1. Introduction
A Supply Chain (SC) can be defined as a network of members linked together by flow of materials, information, and funds with an objective to reduce overall system cost [1]. The supply structure may differ based on the number of intermediate facilities and position of the facilities within the supply chain. In general, the facilities in the supply chain are supplier, manufacturer, distributor, wholesaler, and retailer. Each facility in the supply chain processes order based on the available information and places order to the immediate upstream facility. From available stock, the upstream facility meets the demand of the downstream facility. The downstream facility represents the direction towards the end customer, and the upstream facility is the direction towards the end supplier. Finally, customers collect the product from the last facility of the supply chain. Figure 1 shows a representative supply chain. The goal of an SC is to maximize overall profitability, and it is calculated as the difference between the revenue generated from the customer and total cost incurred across all stages of the SC. The higher the SC profitability, the more successful is the SC. Nowadays the SC success is measured in terms of SC profitability and not in terms of the profits at an individual stage. SC profitability may decrease due to the lack of strategic fit between the competitive strategy and SC strategy. The competitive strategy defines the set of customer needs that it seeks to satisfy through its products and services. The SC strategy determines how the SC should perform with respect to efficiency and responsiveness. To achieve a strategic fit, a company must first understand the uncertainties and capabilities of the SC in
terms of efficiency and responsiveness. So the right balance between responsiveness and efficiency leads to achieve strategic fit [3].

In the present global market, the competition is not between the companies but between the SCs [4]. Hence, the best performing SCs may survive over a long period. The better performance of an SC and also the success of SC members can ensure by the high degree of coordination among members. When the members are not coordinated, it may lead to poor performance of the entire SC. Coordination among members can be achieved by information sharing mechanism [5], and some of the objects in the sharing may include supplier's capacity, customer demand, inventory policies and inventory levels of other members [6]. Some of the factors affecting SC performance are operating conditions or environmental factors and SC decision parameters or internal factors [7], [8]. The paper is organized as follows: Section 2 explains various supply chain performance measures. Section 3 describes major factors that affect the supply chain performance. Finally, in Section 4, we give a few concluding remarks.

2. Supply chain performance measures

“Performance measurement is defined as the process of quantifying the effectiveness and efficiency of an action” [9]. The comparison of performance measures helps to identify a good SC. The performance measures can be classified into qualitative and quantitative categories. Qualitative performance measures are those measures for which there is no direct numerical measurement (such as customer satisfaction, products quality, SC vulnerability, SC resilience) and quantitative measures can be described numerically (such as fill rates, costs, inventory levels, resource utilization) [10]–[12]. The various performance measures noticed in the literature to analyse SC’s are: SC fill rate [3], [13], order variance and Bullwhip Effect (BWE) [14], [15], order variance ratio [13] and Bullwhip Slope (BwSI) [13], [16], inventory variance and zero replenishment phenomenon [17], risk of shortage [18] and Total Cost of the Supply Chain (TCSC) [13], [19].

- SC fill rate: It is an indication of the service level of a company for a product, and it is defined as a ratio of demand met to demand arose in the lost sale environment [3]. The average of fill rates of all the retailers is considered as SC fill rate or customer service level [7]. The fill rate of an SC depends on the inventory policy used [20], [21].
- Bullwhip effect: The increase in demand variability from the downstream stage to upstream stage in an SC is called bullwhip effect [22]. A high value for the bullwhip creates an adverse impact on the performance of an SC [23]. Previous researches confirmed that it could not be eliminated completely, but it can be reduced or controlled [5], [24]. One of the causes of its occurrence is the replenishment strategy or inventory policy used [25], [26]. BwSI is an entire SC measure showing the presence of the bullwhip effect. A high value of the slope means a fast
propagation of the bullwhip effect through the SC, while a low value means a smooth propagation [16].

- Risk of shortage: It can be found by counting the number of stockouts and dividing it by the total number of periods for which demand arises. The retailer risk of the shortage is considered as SC risk of shortage [18].
- Zero replenishment phenomenon: It is defined as the period in which a member does not place an order [27].
- Inventory variance: This metric quantifies the fluctuations in actual inventory in every period [17]. The increased inventory variance will result in higher holding cost and shortage costs.
- Total cost of the supply chain: This cost is related to inventory management and the costs of inventory holding, shortages, ordering, and transportation vary based on the inventory policies used. Hence, the TCSC is equal to the sum of the inventory holding, shortages, ordering, and transportation costs for whole members in all stages of an SC [13]. The order cost is associated with issuing a purchase order to an outside supplier or from internal production setup costs. The major cost ingredients are: making requisitions, analyzing vendors, writing purchase orders, receiving materials, inspecting materials, following up orders and doing the paperwork necessary to complete the transaction. The setup cost comprises the cost of changing over the production process to produce the ordered item. The cost incurred to transport items from one member to another is termed as transportation cost. The cost associated with carrying items is termed as inventory holding costs. Storage and other related costs are included in this cost. The major cost ingredients are: capital, storage, insurance, taxes, damage, theft and obsolescence. The cost associated with not having enough inventory to meet demand is shortage cost. The major cost ingredients are: penalties, lost sales, expediting, loss of goodwill, customer irritation and backorder.

3. Factors affecting supply chain performance

The supply chain performance is influenced by various factors. Some of the main factors are supply chain structure, inventory control policy, information sharing, customer demand, forecasting method, lead time and review period length. These factors are described below:

3.1. Supply chain structure

The number of facilities, the number of stages, and the structure of the material and information flow contribute to the complexity of the chain. The SC structures can be classified as: dyadic, serial, convergent, divergent, conjoined and network. The various SC structures are shown in figure 2.

![Figure 2. Various supply chain structures][28]
• Dyadic: The dyadic structure consists of two business entities (e.g. buyer-vendor) [29].
• Serial: Cascading of several dyadic structures form a serial SC structure, and generally, it consists of retailer, distributor, wholesaler and manufacturer entities or stages [29].
• Convergent: Convergent structures are assembly-type structures in which each node (or facility) in the chain has at most one successor, but may have any number of predecessors [30].
• Divergent: Each node in a divergent has at most one predecessor, but any number of successors [30]. A divergent structure can be observed in an SC in which one supplier distributes stock to its several downstream entities. Mineral processing organizations tend to have divergent structure.
• Conjoined: It is a combination of convergent and divergent SC structures and is observed in web-based retailing [30].
• Network: If an SC structure which is not falling in any of the above structures come under the category of network or general type [28]. It is a complex structure, observed in electronics manufacturing SCs.

As the supply chain structure complexity increases the bullwhip effect generated in the supply chain also increases [31]–[33]. Bottani and Montanari [32] observed that total inventory cost of the supply chain and bullwhip effect would increase significantly as the number of stages in the supply chain increases.

3.2. Inventory control policy
Inventory control means to ensure that the business has the right goods on hand to avoid stock-outs, to prevent shrinkage, and to provide proper accounting. There must be an economic balance between the costs incurred and the costs saved by holding the material in stock. There are two basic decisions that must be made for every item that is maintained in inventory. These decisions have to do with the timing of orders for the item and the size of orders for the item. So inventory control mechanism involves decisions regarding 'when' and 'how much' to order.

There are two independent-demand inventory systems viz., periodic review system and continuous review system. In the periodic review system, the inventory position is reviewed at regular intervals (at review periods), and an appropriate quantity is ordered. So, periodic inventory review involves counting and documenting inventory at specified times. For example, a retail store operating under a periodic review policy might count inventory at the end of each month. Periodic inventory review reduces the time a business owner or manager spends analyzing inventory counts, which allows more time for other aspects of running the business. However, it may not provide accurate inventory counts for businesses with high-volume sales. The owner or manager must make assumptions between inventory review periods regarding inventory counts. This can make it difficult to ascertain when reordering an item is necessary. It also can make accounting less accurate. However, in a continuous review system, reviews are often carried out continuously (after each transaction), and a fixed quantity of the item is ordered if the inventory position reaches the reorder level. Continuous inventory review, also known as perpetual review, involves a system that tracks each item and updates inventory counts each time an item is removed from inventory. Perpetual inventory review permits real-time updates of inventory counts, which can make it easier to know when to reorder items to replenish inventory. This method of inventory review also facilitates accurate accounting, since the inventory system can generate real-time costs of goods sold. The main disadvantage of this type of inventory review is the cost of implementation-bar code scanners, inventory software and computer systems are all necessary to maintain perpetual inventory review.

Inventory policies consider inventory position for placing orders (either for order decision or order size determination) are called inventory position-based policies and the policies that do not consider inventory position are called non-inventory position-based policies. Inventory position at a period is equal to on-hand plus on-order inventory minus backorders where on-hand means the quantity immediately available to meet demand, on-order means the quantity yet to arrive, and backorder means demand that could not be met in the previous periods [34].
3.3. Information sharing
Information sharing can be called as the biggest driver of performance in the SC [3]. Information connects various SC partners and allows them to coordinate activities. Information is crucial to the daily operations at each stage of the SC. An information system can enable a firm to get a high variety of customized products to customers rapidly and to understand the changing customer's tastes and preferences. Continuous sharing of new information with key individuals in a timely and qualitative manner help managers in better decision making, resulting in improved performance [35]. Information sharing in SCs offers many benefits such as reduced bullwhip effect, better coordination among various activities, taking better decisions and reduced uncertainties in SCs [5], [36]. Making information available and sharing it with the partners, an organization can speed up the flow of information within SC, improve productivity and effectiveness and decrease the response to the market time. Thus, information sharing brings competitive advantage for SC partners [35]. Information sharing reduces uncertainty in SC and thus reduces the need for safety stock. Cachon and Fisher [6] studied the impact of information sharing in a divergent SC and the result showed that the information sharing reduce the cost by 22% on average.

3.4. Customer demand
Customer demand pattern is one of the environmental factors affecting the performance of the SC. In most industrial contexts, demand is uncertain and hard to forecast. When customer demand is wildly fluctuating, the member in an SC sends a highly variable order pattern to the associated member in the upper stage, which may cause amplification of order variance (which is termed as bullwhip effect) through the SC. Customer demand volatility also results in high capacity and inventory costs on the manufacturer [37]. Different demand patterns such as constant, seasonal, seasonal with increasing trend, seasonal with decreasing trend are generated from a common demand generator for different values of the various parameters such as base, slope, season and noise influences the service level and total cost of SC [7], [36]. The safety stock required for the case of non-stationary demand is much greater than for stationary demand [38]. The increased visibility of inventory and consumer demand pattern for the players reduces SC inventory costs by enabling the players in developing improved and efficient operations plans at each level in the SC. The inventory related benefits are particularly sensitive to demand variability, the service level provided by the supplier, and the degree to which the order and production cycles are out of phase [39].

3.5. Forecasting method
Lee et al. [40] identified one of the main causes of the bullwhip effect in the supply chain is the use of demand forecasting. In a supply chain, the members need to forecast its future demand, and it is impossible to predict demand with certainty. This uncertainty will result in distorted order quantity and via order variance amplification [7]. The accuracy of forecast highly influences the supply chain performance measures such as inventory cost, backorder cost, lost sales cost, and customer's goodwill. An inaccurate forecast results in underutilization of the factory capacity [41]. Forecast method with appropriate ordering policy can alleviate the bullwhip effect up to 55% [42]. The most commonly used forecasting techniques include simple exponential smoothing and moving average. The simple exponential smoothing technique has an advantage of easy implementation in computer systems as it required fewer data storage [43]. However, the increase in order variance under simple exponential technique is greater than the increase in the order variance under moving average forecast technique [44]. Some researchers [8], [45] analysed the impact of information sharing and forecasting models under different levels of demand patterns and suppliers capacity tightness on a divergent SC having one supplier and four retailers. They found that all the factors significantly affect the SC performances, such as service level and total cost.

3.6. Lead time
The replenishment parameters such as lead time and review period can also affect the performance of SC [46]. The time gap between the receipts of the order to delivery of the product is referred as lead
time, which is the sum of order lead time and delivery lead time. One of the causes of the bullwhip effect is the long lead time [47]. Under long lead time, the fluctuation in orders is more, which may results bullwhip effect [48]. The experimental study of Steckel et al. [49] found that lesser the lead time, the lesser the bullwhip effect. Long lead also results in either a shortage or accumulation of total inventory in the supply chain. Shorter lead time helps the efficient operation of the entire SC. Heydari et al. [50] analysed the impact of lead time variability in BWE for a serial four-stage SC where the members followed lead-time-sensitive ordering policy with zero safety stock and is operated under lost sales environment. Chaharsooghi and Heydari [51] developed a simulation model to analyse the effect of mean and variance of lead time in a serial four-stage SC and found that the effect of lead time variance on SC performance is much greater than the effect of the mean lead time. Khosroshahi et al. [52] noticed that the parameter of moving average method and lead time have a positive impact of bullwhip effect.

3.7. Review period length
Review period length refers to the time between the successive evaluations of inventory status to determine whether to reorder or not. The optimum selection of the review period depends on the nature of the demand of the product. Sezen [53] studied the changes in performance of a two-stage supply chain under various lengths of review period with lost sales environment and found that for products having high fluctuating demand shorter review periods are preferable to avoid long-lasting stock-outs. Also, for fast-moving consumer goods having a high carrying or shortage cost long review periods should be avoided. The study of Movahed and Zhang [54] for a serial three-stage SC under uncertain review period showed that a shorter review period is optimum to reduce the order variance; whereas a longer review period should be chosen to reduce the total expected cost. So a trade-off between the length of the review period and cost of the supply chain is essential.

4. Conclusion
The performance of the supply chain is affected by various factors. Some of the factors identified in the present study are the supply chain structure, inventory control policy, information sharing, customer demand, forecasting method, lead time, and review period length. All factors are supply chain decision parameters or internal factors except the fourth factor, which is an operating condition or environmental factor. The bullwhip effect in the supply chain increases as the supply chain structure complexity increases. Inventory control policy used in a supply chain plays a vital role in the performance of the supply chain. Information sharing is the biggest driver of performance in the supply chain. Continuous sharing of information helps managers in better decision making, which improves the performance of the supply chain. The highly fluctuated customer demand increases the bullwhip effect and inventory cost in the supply chain. The accuracy of forecast highly influences the supply chain performance. Shorter lead time helps the efficient operation of the entire supply chain. A longer review period should be chosen to mitigate the total inventory cost of the supply chain. The optimum selection of parameters of all the factors results in better performance of the supply chain.

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