Service Performance of Some Supply Chain Inventory Policies Under Demand Impulses

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Abstract: This paper attempts to study the impact of impulsive demand disturbances on the service performance of some inventory control policies. The supply chain is modeled as a network of autonomous supply chain nodes. The customer places a constant demand except for a brief period of sudden and steep change in demand (called demand impulse). The service performance of some inventory control policies is studied under increasing number of demand impulses. It is found that the independent decision making by each node leads to bullwhip effect in the supply chain whereby demand information is amplified and distorted (as reflected by poor service performance). However, under a scenario where retailer places a constant order irrespective of the end customer demand, the service performance does not deteriorate along the supply chain. The service performance of all the supply chain nodes remains same when only the actual demands are transmitted by each node. The results also showed that the inventory policy which is best for one supply chain node is generally less efficient from a supply chain perspective. Moreover, the policy which performs poorly for one node can be most efficient for the supply chain. In a way, our results also provide a case for coordinated inventory management in the supply chain where all members prepare a joint inventory management policy that is beneficial for all the supply chain nodes.

Keywords: Inventory Management, Supply Chain, Simulation, Impulse Demands

1. Introduction

Supply chains can be structurally considered as network of independent and autonomous entities which work in unison towards some common objective. Each entity or member of the supply chain can be represented as a node on the supply network. Since each node of the supply chain is an autonomous member, each node takes decisions in accordance with what it perceives is best for it. There are numerous examples in supply chain literature that demonstrate that this autonomous decision making by each node leads to overall poor performance of the supply chain. They also lead to the phenomenon of *Bullwhip Effect* whereby the demand information is delayed, distorted and amplified at each supply chain node (see Lee *et. al.* 1997*a* and 1997b).

From a service performance (or service quality) point of view, this autonomous decision making leads poor performance of the supply chain as demonstrated by simultaneous occurrence of poor service levels and very high inventory carrying costs. In other words, the inventory policy followed by a supply chain node affects the inventory related performance of the supply chain to a very large extent. The impact of various inventory policies on the supply chain performance is widely studied (Atkins and Iyogun 1988, Viswanathan 1997, Nielson and Larsen 2005). However, the performance of these policies under different degrees of variability has not been studied well.

Demand impulse is a unique kind to demand disturbance where the demand remains constant except for a short period of very large demand fluctuation. Hence, impulse can be considered as the smallest disturbance that can occur in a demand pattern. As this disturbance does not change the mean demand substantially, the impact of this impulse stabilizes automatically over time. However, this small disturbance can have unexpected effects on the entire supply chain depending on the inventory policies followed by different supply chain nodes. More number of impulses can be added to the demand pattern to simulate different degrees of demand variability.

This paper attempts to study the impact of impulse demand disturbances on service performance delivered by different supply chain inventory policies through simulation. Each member of the supply chain is modeled as an independent entity, who takes its decisions autonomously. The impact of these policies on each member of the supply chain and the entire supply chain is then studied by simulating the decision making process at each node working with some pre-defined inventory policy under different degrees of impulse demands. The rest of the paper is presented as follows. The next section provides brief review of inventory management literature to highlight the scope for our research. This is followed by the presentation of a conceptual supply chain model and its definition in context of the study. The experimental results are presented in next two sections: one showing the impact of demand impulses in individual supply chain nodes and the other highlighting the overall impact of these disturbances on the supply chain. The implications of these findings on managers are discussed in the subsequent section. The last section concludes the paper by presenting the key research findings.

2. Literature Review

The inventory policies can be broadly classified in two categories depending on the review period. The first category is the continuous review policy where the inventory position is continuously monitored and new orders are triggered by some events. The *(s, Q)* policy and *(s, S)* are two such inventory policies which are defined by two parameters. The first parameter is called the reorder point (or level) s. The second parameter is the quantity to be ordered Q for *(s, Q)* policy and order upto level S for *(s, S)* policy. In *(s, Q)* policy, each time the inventory falls below the reorder level, a new order of quantity Q is placed. Similarly in *(s, S)* the order quantity is so as to make the total inventory level to S.

The second type of inventory policy is the periodic review policy. In a periodic review policy, the inventory position is reviewed only once every T_i periods. The length of T_i is always some integral multiple of the base period. A comparison of continuous review policies and periodic review policies by Atkins and Iyogun (1988) revealed that periodic review policies have twin advantage over continuously review policies. They are simpler to compute and they also outperform the continuous review policies significantly. A periodic version of the *(s, S)* policy was suggested by Viswanathan (1997). In this policy, the inventory position is analyzed at the end of each review period and *(s, S)* is applied to each item, such that each item with inventory level lower than the reorder level is included in the order. Nielson and Larsen (2005) evaluated the performance of an *(s, S)* policy for a multi-product supply chain where the demand of each product followed a Poisson process. They found out that *(s, S)* policy performs best among the considered policies.

Many inventory policies can be found in literature, which cater to one form of demand or other (Schwartz *et. al.* 2006, Aburto and Weber 2005, Xu *et. al.* 2003). A generalized order-up-to policy having highly desirable properties in terms of order and inventory variance and customer service levels was studied by Disney *et. al.* (2006). Brecman *et. al.* (1989) proposed a heuristic algorithm that incorporates the capacity of transportation and storage resources and transportation costs. Viswanathan and Piplani (2001) proposed a model to study and analyze the benefits of coordinating supply chain inventories through the use of common replenishment epochs or time periods.

One of the desirable features of a good inventory policy is its ability to accommodate the demand uncertainty. In this direction, many researchers have modeled the supply chains under stochastic demands (Chung *et. al.* 2006, Amin and Altiok 1997, Fliesch and Tellkamp 2005, Zhang 2005). Hosoda and Disney (2006) analyzed a three echelon supply chain with autoregressive end consumer demand and obtained exact analytical expressions for bullwhip and net inventory variance at each echelon in the supply chain. Disney and Towill (2003) presented a discrete control theory model of a generic model of a replenishment rule. The paper by Giannoccaro *et. al.* (2003) presents a methodology to define a supply chain inventory management policy, which is based on the concept of echelon stock and fuzzy set theory.

One of the methods of improving the supply chain performance is through coordinated inventory management. In this setting, all the supply chain members jointly decide about the inventory policies rather that each member taking its inventory decision independently. Many papers in literature demonstrate the improvements that can be achieved by using coordinated inventory management (Boute *et. al.* 2006). The disparity between local and central planning of multiple-stage, deterministic demand inventory systems was investigated by Simpson (2006) under a broad range of environmental factors. Gavirneni (2005) showed that in the presence of information sharing, the supply chain performance can be improved by the supplier offering fluctuating prices. Sahin and Robinson (2005) mathematically modeled and developed simulation procedures to analyze the manufacturer's and vendor's control policies under five alternative integration strategies. Sucky (2005) studied the coordination of order and production policies between buyers and suppliers. The paper by Zhang *et. al.* (2006) evaluated the benefit of a strategy of sharing shipment information, where one stage in a supply chain shares shipment quantity information with its immediate downstream customers (a practice also known as advanced shipping notice). Chu and Lee (2005) modeled as two member supply chain as a Bayesian game and found out that two conditions affect the information sharing in the supply chain: the cost of revealing the information and the nature of market demand signal that the retailer receives.

This literature review highlights the need to study the supply chains under dynamic demands. One of the ways to study the dynamism of the system in a controlled manner is by incorporating the impulses in the actual demand. Moreover, a generic model of the supply chain needs to be developed that can reflect the autonomous decision making process of each node. This model is in the next section.

3. Conceptual Model of a Supply Chain

The supply chain can be considered as a *system* composed of a number of *objects*. A *system* is defined to be a collection of entities, e.g., people or machines that act and interact together toward the accomplishment of some logical end (Schmidt and Taylor 1970). The selection and meaning of the system depends on the objectives of a particular study. The collection of objects that compose a system for one study might be only a subset of the overall system for another (Law and Kelton 1991). For a discrete system, the variables that define the state of the system change instantaneously at separated points in time. The "points in time", at which the state of the system changes are called *events*. Flexibility in systems helps to exploit the decision points at chosen events to control the flow of entities leading to performance improvements (Wadhwa and Rao (2005). Supply chains viewed as flexible systems can also significantly benefit from this research.

For the purpose of simulating the supply chain, it can be modelled as discrete system composed of many objects. Some objects flow through the supply chain while some others remain in it and modify the flowing objects. We have defined the flowing objects as *entities* and the non-flowing objects as the *resources*. Some resources also serve as *decision points*. In other words, they determine the course of some other action. The points where the decision flow and information flows meet are the decision points and the points where the material flow and resource flows meet are the action points (Wadhwa and Browne 1989, Wadhwa *et. al.* 2001, Wadhwa and Rao 2002, Wadhwa and Rao 2003). The result of an action is the transformation of the material. This view was very effective in analysing the manufacturing systems where transformation of the material always takes place. But supply chain system includes both manufacturing and non-manufacturing nodes. Moreover, no transformation of the material takes place in the non-manufacturing nodes.

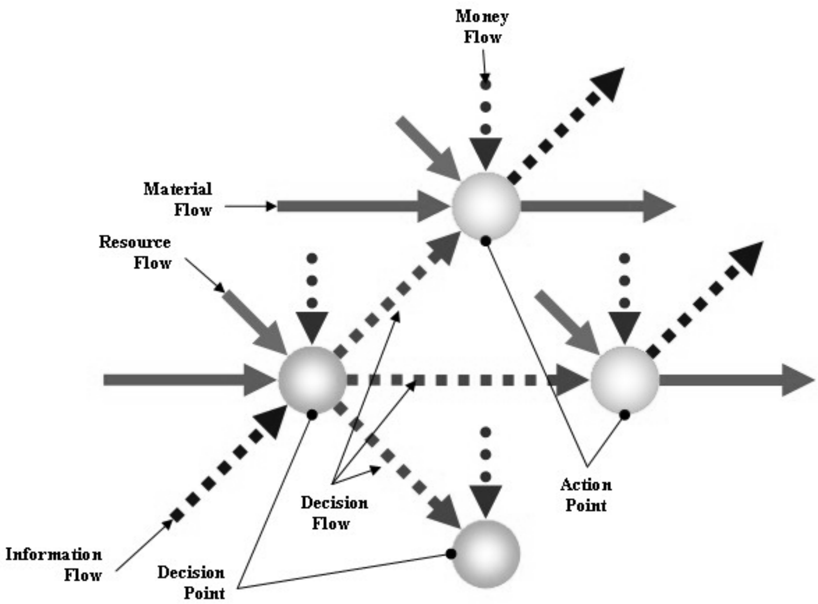

Figure 1. Multiple entity flow perspective

We extend this framework to include both manufacturing and non-manufacturing nodes. For this purpose, an action is defined as a sequence of events that intentionally changes the state of the system. Since an action is always intentional, it includes only the intentional events. Now a decision can be defined as something that determines *what*, *when*, *where*, *who* and *how* of an action. Therefore, a decision always precedes an action. In our extended framework (shown in Figure 1), the decision points are treated as the points where all the other entity flows meet. The decision point makes a decision about which action to initiate. Completion of an action may also lead to some other decision or action. This decision may either lead to some other action or some other decision also. Depending on the material flow, there can be four types of actions:

- *Material In*: Material Storage
- *Material Out*: Material Release from a store
- *Material In Material Out*: Material transformation, similar to the action point described by Wadhwa and Rao 2003.
- *No Material Flow*: All other types of actions

Using this model, any system can be modelled as a chain of action and decision points. For the purpose of experiments, the supply chain was modelled as a sequence of action and decision points. Each supply chain node was treated as a decision point which is connected to other such nodes by some relationship. In our model, only two kinds of relationships: buyer and seller were sufficient to define the entire supply chain. Whenever a demand arrives to the node, it selects the specific action depending on its inventory policy. This leads to an action of releasing the required quantity of material. This action leads to a decision regarding reordering. Depending on the inventory policy, the decision regarding reordering is made. The order generated by this node is treated as demand for the seller of this node. When the material supplied by this node is received by the buyer, it has to made decision to store or supply the material (if there are backorders). This sequence of events is repeated for all the nodes in the supply chain.

4. Model Definition

Table 1. Model parameters

S. No.	Model Parameter	Value
1.	Demand	Constant demand of 40 units per day
2.	Transportation Lead time	Same lead time of 2 weeks between each node pair.
3.	Ordering Lead time	Same lead time of 2 weeks between node pair (lead time of 1 week for supplier who produces the product).
4.	Number of nodes	4 (Retailer, Wholesaler, Manufacturer, Supplier)
5.	Period	52 weeks

4.1 Model parameters

A linear supply chain with four nodes was considered for our experimentation (see Figure 1 for details). The objective was to study the impact of demand impulses on the stability of the supply chain for different inventory policies. For this purpose, the linear supply chain was first balanced with a constant demand and then demand impulses were introduced. The balancing of the demands assumed that all inventory policies were periodically-monitored and the orders are placed once in each period. However, for simplicity and ease of comparing different inventory policies, the period of review was taken as one week. Each inventory policy places new orders in a review period if some conditions are satisfied. These conditions are different for each policy as explained below:

(i.) *Demand Flow:* As the name suggests, this policy just transfers the actual demand from one node to another with transforming it. The demand only gets delayed by the time equal to the ordering lead time.

(ii.) *Order Q:* In this policy a fixed quantity of the product is ordered each period irrespective of the actual demand. Therefore, this policy does not consider the input demand at all.

(iii.) *Order Upto:* In this policy, an *order-upto level* is selected first. This level indicates the maximum inventory to be kept. Whenever, the actual inventory falls below this level, an order is placed so that the available inventory and the ordered quantity become equal to the *order-upto* level.

(iv.) *(s, Q) Policy:* This policy requires two parameters for definition. The first parameter (s) is called the reorder level. A new order is placed as soon as the inventory falls below this level. The other parameter is the order quantity (Q). Therefore, in this policy, a fixed order quantity is ordered as soon as the actual inventory falls below the reorder level of inventory.

(v.) *(s, S) Policy:* This policy is similar to the *(s, Q)* policy with a difference of one parameter. Instead of a fixed quantity Q a variable quantity is ordered so that the sum inventory and the ordered quantity become equal to some predefined maximum inventory level or order up to level (S).

(vi.) *Moving Average Policy:* In this policy, the quantity equal to the average demand of previous *n* periods is ordered. If previous periods are less than *n,* an order equal to the mean demand in available periods is placed. If the value of *n* becomes 1, this policy becomes equivalent to the demand flow policy. If the value of *n* is greater than the time of the simulation run (or the time span studied), this policy always takes into consideration the average of demand in all the previous periods. In our simulation study, we have considered *n* to be equal to span of simulation. Therefore, this policy is referred to as *Average Demand* Policy.

4.2 Performance Metrics

Performance metrics were required to compare the results of the simulation experiments for different inventory policies. These performance metrics were individually calculated for each of the supply chain nodes. A brief description of each follows:

(i.) *Backorders:* As discussed above, the backorders were represented by negative inventory. In other words, this represents the demand quantity that a specific node could not fulfill on time.

(ii.) *Stock-outs:* It is a situation when a supply chain node is not able to fulfill the requested demand, either fully of partially. For a specific point of time, its value is either true or false.

Each of these metrics can be converted to cost terms by attaching a cost component to each metric. We have not included any cost terms because the costs of these metrics are different for each supply chain (and may also different for each node in the supply chain as all nodes are autonomous members).

4.3 Setting the policy parameters for each policy

Each policy was first balanced so that all of them gave same results for the test demand. For this purpose, the policy parameters and initial inventory at each node was varied, so as to result in zero inventory in steady state condition. Only the inventory in steady state condition was considered significant because some inventory always remains during the initial time for most of the policies (primarily because of initial inventory). Another factor influencing the presence of inventory in transient conditions is the lead time involved in ordering and transportation. An order placed by buyer node takes a finite amount of time to reach the seller node. The seller node has to keep some inventory up to this time to fulfill this demand. However, in steady state condition, the inventory reduces to zero, as the supplies and demands match each other. The settings for each inventory policy and the reasons for each setting is discussed below.

- *Demand Flow:* The test demand was a constant demand of 40 units per week. To fulfill the current obligations, each node has to keep a minimum of 40 units. Due to finite lead times (both ordering and transportation), the quantity ordered by a node is received only after some finite amount of time. We have assumed the ordering and transportation lead times to be 2 weeks each. Therefore, each node has to keep an initial inventory equal to four weeks of demand. As a result, an initial inventory of 160 units was allocated to each node. Total lead time of the supplier was 3 weeks; initial inventory of 120 was allocated to it.
- *Order Q:* In this policy, orders are placed even when no there is no demand. Therefore, inventory builds up for each node, until the actual demand is received. As a result, all nodes only need to keep an inventory equal to the value of demand per week (40 units).
- *Order Upto:* No inventory build up occurs in this policy in the initial time periods. As a result, an initial inventory has to be allocated so that each node is able to suffice the demands until they receive their corresponding ordered quantities from their sellers. This initial inventory for each node was kept same as that for demand flow policy.
- *(s, Q) Policy:* The initial inventories for each node were same as those for demand flow policy. A reorder point (*s*) of 160 and order quantity (*Q*) of 40 was set for this policy.
- *(s, S) Policy:* Initial inventories were kept same as the demand flow policy. Both reorder point (*s*) and reorder level (*S*) were set to be 160 units.
- *Average Demand Policy:* The initial inventories were kept same as those for demand flow policies.

These setting resulted in zero inventories for each of the policies under steady state conditions. The inventories for demand flow policy are shown in Figure 2 as an illustration.

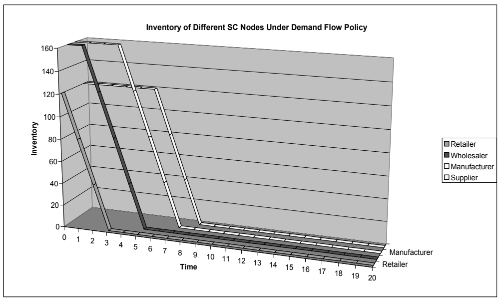

Figure 2. Inventory of supply chain nodes under demand flow policy

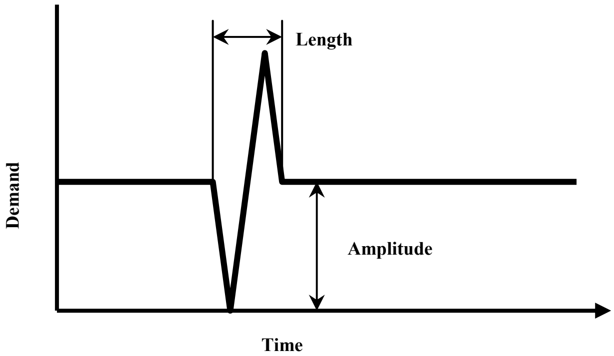

Figure 3. Impulse Demand

4.4 Demand Impulses

We considered the demand impulses as demand fluctuations that occur instantly but do not change the mean demand. These fluctuations last for a very short time, but their after-effects remain in the supply chain for as comparatively longer time period. As shown in Figure 3 an impulse can be defined along two primary variables: *Amplitude* and *Length*. For the experimentation purposes, amplitude is taken equal to the mean demand i.e. 40 and length of the impulse is taken as 2 weeks. The number of simultaneous impulses was varied from 1 to 6 to induce different degrees of variability in the supply chain. The impact of this variability on the performance of each supply chain node and on the entire chain was then evaluated based on the performance metrics recorded for each inventory policy. The subsequent sections discuss the results of these experiments.

5. Impact of Demand Impulses on the Performance of SC Nodes

Four supply chain nodes were considered in the study. The impact of demand impulses on each node is described separately for each node in this section. For each node, the impact of demand impulses on different performance metrics under different inventory policies is discussed.

5.1 Impact on Retailer

The backorders observed for different degrees of demand impulses on different inventory policies are different (see Figure 4). For the case of *Order Q* policy, the backorders at the retailer end are always zero. This is because the retailer places orders irrespective of its demand. Since inventory builds for the retailer in the periods of no demand, the retailer is able to fulfill the demand during the periods of steep rise in demand. *Demand Flow* and *Order Upto* behave identically in terms of backorders. The number of backorders increase continuously but the rate of increase in backorders decreases after two impulses. Both *(s, S)* and *Average Demand* are able to stabilize the number of backorder but to different degrees. While *(s, S)* policy completely removes the effect of the demand impulse for two or more impulses, *Average Demand* policy induces its own variability in the system. As a result, the backorders are comparatively more for this policy. Another implication of this induced variability is that the backorders do not follow a smooth curve as for other policies. The observations for *(s, Q)* were peculiar, in the sense that backorders first increase and then decrease. A deeper observation in this case showed that this policy was not robust enough to accommodate even one demand impulse. The balance of the inventory and demand was disturbed even for one demand impulse. Just one disturbance leads to a situation where the retailer orders only the pre-defined order quantity *Q* even though it has backorders. As the number of impulses increase, the inventory is built up during periods of zero demand, thus reducing the backorders in the subsequent periods.

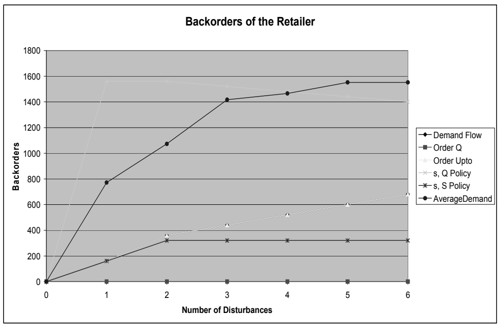

Figure 4. Retailer's backorders

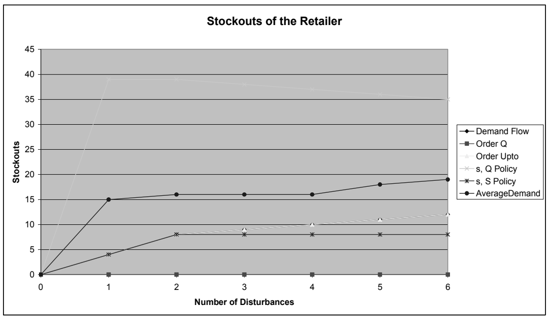

Figure 5. Retailer's stockouts

The retailer's Stockouts are shown in Figure 5. Stockouts show a similar trend as for backorders for all policies. For the A*verage Demand* policy, the variation is not smooth. This is because of two reasons: the induced variability and the nature of stockouts. By their definition, stockouts do not consider the quantity. Therefore, its variation is not same as that of backorders.

5.2 Impact on Wholesaler

The demand received by the wholesaler is dependent on the orders placed by the retailer. The orders placed depend on the inventory policy used by the retailer. Therefore, the demand of the wholesaler is also dependent on the inventory policy of the retailer. Hence, the demand received by the wholesaler is different for each inventory policy. For instance, under Order Q policy, the wholesaler receives a constant demand of 40 units irrespective of the actual customer demand. As discussed below, the demand patterns also affect the inventory levels of the wholesaler.

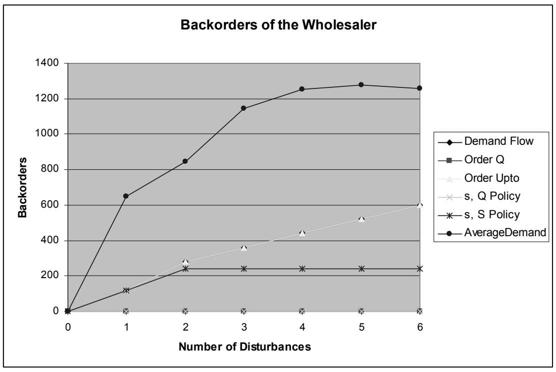

Figure 6. Wholesaler' backorders

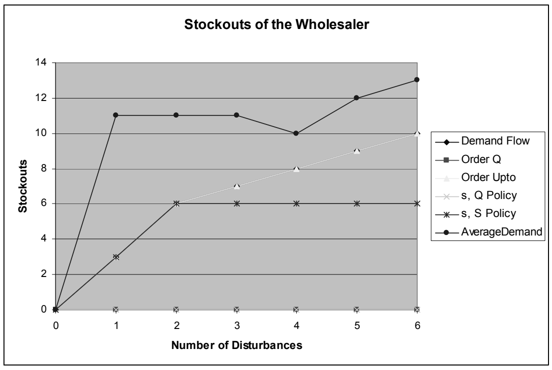

Figure 7. Wholesaler's stockouts

Both these metrics follow the similar pattern as that for total inventory and standard deviation of inventory with a few differences (as shown in Figure 6 and Figure 7 respectively). One peculiar observation is that the number of stockouts actually reduces for *Average Demand* policy with 4 demand impulses. However, for the same number of impulses, the backorders increased under this policy. Therefore, we believe that this difference in stockouts is only due to the variability induced by this inventory policy.

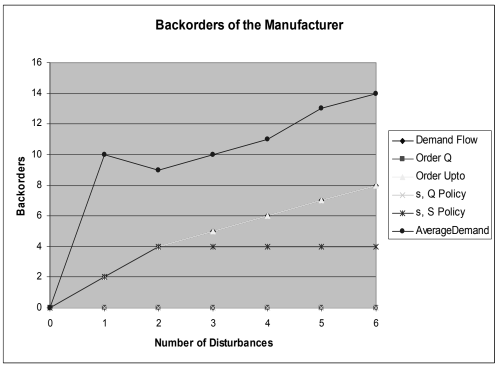

Figure 8. Backorders of the manufacturer

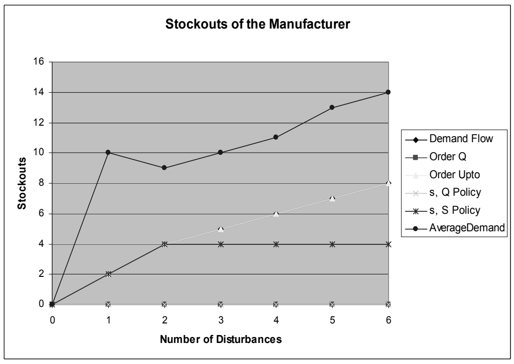

Figure 9. Stockouts of the manufacturer

5.3 Impact on Manufacturer

The backorders and stockouts shown in Figure 8 and Figure 9 reflect no abnormal observation except for a small reduction with 2 impulse demand under *Average Demand* policy.

5.4 Impact on Supplier

Some abnormal observations are present in the plot of backorders (see Figure 10). The total backorders actually reduce for a demand with more than 4 impulses. One of the reasons for this behavior is a very high level of inventory available with the supplier. Another reason is again the induced variation in the system. This can be demonstrated by comparing this trend with the number of backorders during the same periods (as shown in Figure 11). The backorders reduce for 5 impulse demand but stockouts increase during the same demand pattern.

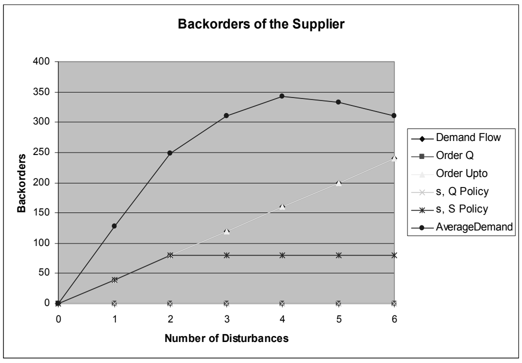

Figure 10. Backorders of the supplier

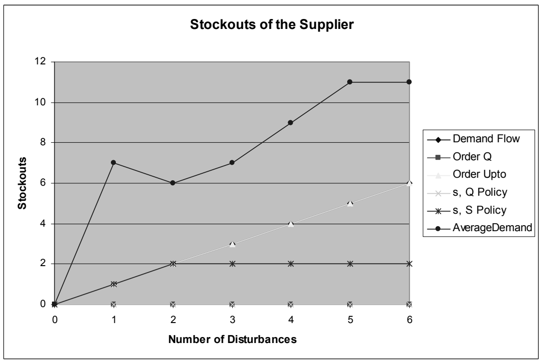

Figure 11. Stockouts of the supplier

6. Impact on the Entire Supply Chain

The impact of demand disturbance on the entire supply chain can be viewed along two separate lines: the impact of demand disturbance on the collective performance metrics and the impact on the performance metrics along the supply chain. For the former case, the collective measure of each performance metric was calculated by the taking the sum of the individual metrics for each supply chain node. For instance, the total inventory in the supply chain was found out by adding the total inventories at all the four nodes. For comparing the performance along the supply chain, the worst-case demand of 6 impulses was considered for comparison.

6.1 Collective Impact on the Supply Chain

Since demand disturbances are not transmitted to the other supply chain nodes when using *Order Q* policy, no backorders exist under this policy (see Figure 12). In our demand pattern, a period of zero demand was followed by a period of a steep demand. The inventory buildup in the period of zero demand accommodates the steep demand in the subsequent period. Among the other policies, least backorders occur with *(s, S)* policy. The *(s, Q)* policy stabilizes most quickly although it leads to higher inventory in the steady state. All other policies show an increasing trend with the number demand disturbances. However, the backorders were maximum for *Average Demand* policy. The variation of backorders (as shown in Figure 13) is similar to the variation of backorders.

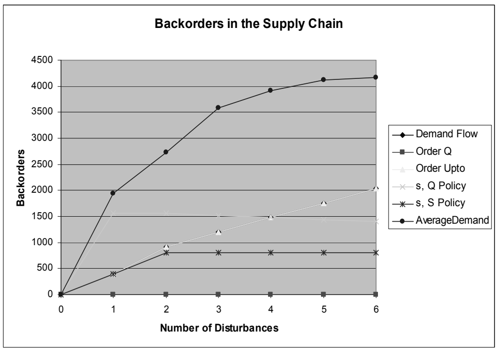

Figure 12. Backorders in the supply chain

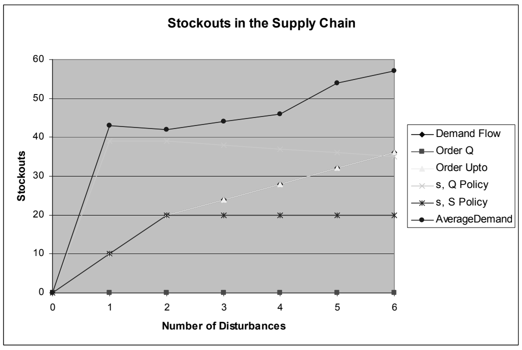

Figure 13. Stockouts in the supply chain

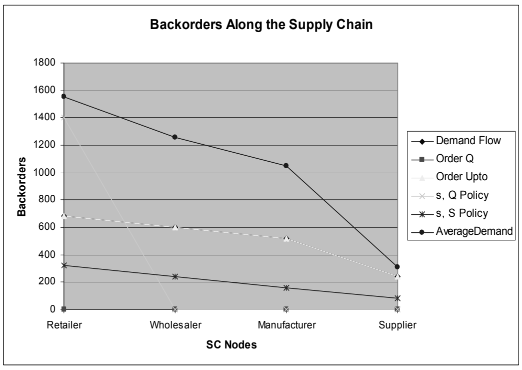

Figure 14. Backorders along the supply chain (for 6 impulse demand)

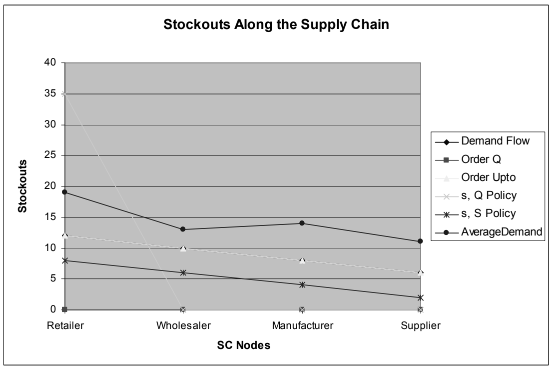

Figure 15. Stockouts along the supply chain (for 6 impulse demand)

6.2 Impact along the Supply Chain

The impact of demand disturbance is different for each supply chain node even for same inventory policy. For analyzing the impact of demand disturbance along the supply chain, the performance metrics obtained by using the 6 impulses demand were compared for each inventory policy. Backorders and stockouts reduce as we move higher up the supply chain (see Figure 16 and Figure 17). Order Q policy gives neither backorders nor stockouts. The reasons for this are already discussed above. Next, the (s, Q) policy does not transmit any demand fluctuations along the chain. Hence, there are no backorders or stockouts higher up in the chain even though retailer has maximum backorders and stockouts as compared to other policies. Taking supply chain as a whole, (s, S) policy leads to lesser number of backorders and stockouts as compared to (s, Q) policy. However, the stockouts and backorders are distributed to each node in the supply chain.

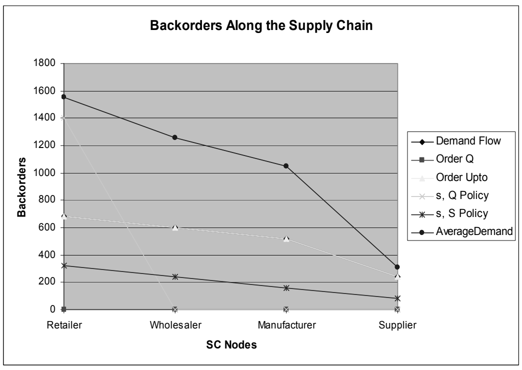

Figure 16. Backorders along the supply chain (for 6 impulse demand)

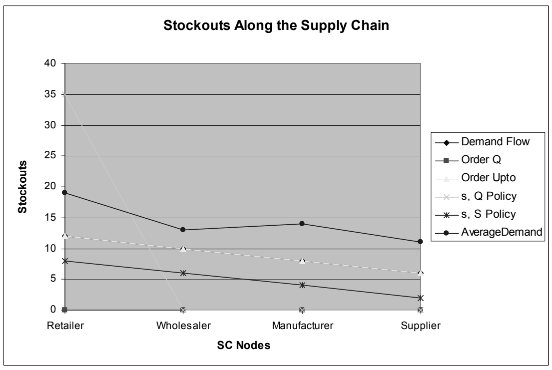

Figure 17. Stockouts along the supply chain (for 6 impulse demand)

7. Research Implications

This demand variability is present in supply chains but their impact on whole supply chain was not studied well. As a result, making suitable ordering decisions becomes difficult for the managers. Our results show the effects of demand disturbances on the performance of each member of the supply chain. In our experimental study, the impulsive demand fluctuations were used to induce controllable variability in the supply chain. This induced variability affected each supply chain node differently, based on the inventory policy used by that node. Our studies revealed the impact of each inventory policy on the supply chain under different degrees of demand disturbance.

It was found that the inventory policies that are most efficient for one particular node are not necessarily efficient for the entire supply chain. A particular case is that of *Order Q* policy which had the worst performance for the retailer. However, from the supply chain perspective this simple inventory policy had many advantages over other complex inventory policies. First of all, this policy leads to best performance of all nodes other than retailer, both in terms of inventory holding and service level. Secondly, this is the only policy where the variance of inventory reduces along the supply chain. This is because all the demand variability is absorbed by the retailer. This observation has tremendous repercussions for the supply chain managers. This provides a justification for having mutual trust and understanding among the supply chain members. By coordinated inventory management, the demand disturbances could be restricted only upto the retailer and a joint inventory policy arrive at. The overall performance of the supply chain could thus be improved by this joint inventory policy.

To perform efficiently, the supply chain nodes need not apply complicated tools or share accurate demand information to all the members of the supply chain. By sharing only the partial information about the mean demands and ordering only as per the average demand improves the overall performance of the supply chain significantly. On one side, it dampens the demand variability of higher level nodes. From the retailer's perspective, the fluctuations in demand may cancel out each other and may not lead to very poor performance. Additionally, the retailer can keep some level of safety inventory to take care of eccentric demand fluctuations. This may lead to additional cost at the retailer's end. Under these conditions the other supply chain nodes should apply some mechanism by which they can induce the retailer to their requirements. Some form of quantity discounts or profit sharing mechanism may be effective to motivate the retailer to absorb demand variability up to itself.

Second important observation is regarding the policies that take out the average demand for calculating the order quantity. It was observed that these policies (*Average Demand* policy) perform worst in stochastic demand situations. Under this policy, each member in the supply chain tries to play safe and keeps the inventory to some current inventory level based on the demand perceived by that node. Additionally, some safety stock may be kept to accommodate unexpected demand fluctuations. These two factors distort the actual demand and the corresponding node, in turn, sends this distorted demand to the higher node. Under this setting, it is imperative that actual demand information is available to each node. But if all the supply chain nodes work independently, the information sharing may not be fruitful. However, this policy can perform better than other policies when the demand follows a particular trend.

Another observation that needs to be highlighted is regarding the demand flow policy. Under this policy, the demand is transferred from one node to another without being distorted. This policy does not lead to demand amplification or increase in demand variability. This can be considered as a special case of full information sharing. The results from this policy show that it has just one weakness: it delays the demand information in accordance with the order lead times. This weakness can be partially eliminated by using Information and Communication Technology (ICT) whereby demand information can be transferred over the internet. The transportation lead times can be reduced by using efficient logistics. However, it needs to be pointed out that transportation lead time cannot be brought down to zero. This policy also calls for mutual faith and understanding among all the supply chain members.

8. Conclusions

This paper attempted to study the impact of impulsive demand fluctuations on different inventory policies used in supply chain. A generic object-oriented framework was used to model the autonomous decision making process at different supply chain nodes. This generic framework was used to replicate the behavior of a four node single-product linear supply chain. A comparison of different inventory policies revealed that simpler inventory policies are better prepared to dampen or even reduce the impulsive demand fluctuations. In particular, ordering a fixed order quantity rather than the quantity determined by inventory position or demand history was found to be more efficient under impulsive demand fluctuations. Another important finding was that the inventory policy that was most beneficial for one node resulted in overall poor performance of the supply chain. Moreover, the inventory policies that take previous demand information tend to magnify and distort the actual demand variations. For instance, the *Average Demand* policy was found to perform poorly under impulse demand fluctuations. The findings from this research are significant for the supply chains facing stable but fluctuating demand. We have shown that, under this demand pattern, the best policy is not to transmit these fluctuations along the supply chain. This is possible by ordering a fixed order quantity in each period. Although this leads to somewhat poor performance of the retailer, it proves to be most effective for all other supply chain nodes. These finding also provide an additional motivation for coordinated inventory management in supply chain by demonstrating that the inventory policies that are best for one supply chain node are more often than not poor from the supply chain perspective.

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