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INTERACTIVE EFFECT OF FIXED TIME ORDER STRATEGIES WITHIN A SUPPLY CHAIN ON ACTUAL IN-STOCK PROBABILITIES

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INTERACTIVE EFFECT OF FIXED TIME ORDER STRATEGIES WITHIN A SUPPLY CHAIN ON ACTUAL IN-STOCK PROBABILITIES

By

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1. Abstract

This report mainly deals with the interactive effect of different in-stock probabilities used by every individual in a supply chain. Based on a simulation for 10,000 weeks, the effects of varying in-stock probabilities are observed. Based on these observations, an individual in a supply chain can take counter measures in order to avoid stock out chances hence maintaining profits.

2. Introduction

2.1. Project Aim –

The main objective of this project is to study and analyze the interactive effect of different in-stock probabilities between different individuals in a supply chain using fixed time ordering quantities.

According to (Chopra 2004) a supply chain consists of all parties involved directly or indirectly in fulfilling a customer request. A supply chain is a system where multiple individuals form a chain to transform raw materials into finished products in order to be delivered to the end customer. Management of the interaction, flow of materials, information and finances between these individuals in a supply chain can be defined as supply chain management. Main objective of a supply chain management is to maintain a high velocity and steady flow of materials in a supply chain with maintaining the right quality and efficient use of finances. In order to maintain a steady flow of materials, ordering of parts or widgets should be enough to fulfill the orders placed by the each individual's customer.

Fixed time ordering strategy is one of the widely used strategies in inventory management. As the name suggests orders placed by the individual is periodically i.e. weekly, fortnightly or monthly. Safety stocks are maintained in order to avoid any stock out chances for any customer orders till the next shipment of parts arrives. Safety stock in fixed time order strategy is decided on the percentage of the inventory. Hence the main object of this report is to see how different in-stock probabilities can affect a whole system.

2.2. Application of the Project –

This project focuses on supply chain management and inventory management. Inventory management is important for every link in a supply chain. Since the project deals with fixed time order strategy, it can be applicable to supply chains following the same inventory control methods. The results obtained from this project can be used to better understand the system followed by a company (business unit or corporation). Effect of different in-stock probabilities can help improve overall efficiency of a company (business unit or corporation) internally or externally. Supply chains exist within a company (business unit or corporation) as internal supply chain and externally with two or more companies (business units or corporations) as external supply chain.

Since the project deals with inventory control, managers in a company (business unit or corporation) following fixed time order strategy can make effective decisions regarding their orders and inventory status. Results obtained from this project might not be very accurate. This is so because results obtained are based on a computer simulation where all factors are controlled and adjustable. Even though the result might not be true to a real life scenario they still provide an insight on possibilities to different outcomes for managing orders and safety stock levels.

3. Supply Chain Management –

3.1. What is a Supply Chain?

As Jacobs and Chase (2011) said, Supply Chain Management can be defined as design, operation and improvements of the systems that create and deliver the firm’s products and services. Hence we can say that a supply chain not only consists of a manufacturer and supplier but also includes various other individuals such as transporters, warehouses, retailers and the customers. A supply chain not only depends on functions such as order receiving and fulfilling them but also involves functions such as new product development, marketing finance and customer service.

Supply chain refers to processes that move information and material to and from the manufacturing and service process of the firm. Chopra and Meindl (2004) say that a supply chain is dynamic and involves the constant flow of information, product and funds between different stages. A simple example of a supply chain can be illustrated by online ordering system by Dell Computer. A typical customer browses through the catalog of products by Dell Computers. This catalog provides information about all the products, their pricing, different machine configurations and availability. Customer places an order on the company website. This order is then sent to the Dell Assembly plant and all the part suppliers and their suppliers. All the suppliers in the chain ship their parts to their respective customers. Upon availability of all the parts they are assembled and then shipped to the customer. As seen, apart from flow of parts there is flow of information and required funds for the parts within the various stages of the supply chain.

Hence from the above example, we can say that customer is an integral part of a supply chain. All the activities of the supply chain begin at the supply chain. A typical supply chain may involve a variety of stages. These stages may include –

- Customer
- Retailer
- Wholesaler
- Distributor
- Manufacturer
- Raw material supplier

In order to fulfill a customer’s order, all the stages of the supply chain need an efficient way to operate. As told by Jacobs and Chase (2011), work involved for effective management can be categorized in five process. They are as follows.

Planning – In planning a firm must determine how to fulfill all the incoming demands with the available recourses. A major aspect of planning is to analyze the firm related factors of the supply chain so that it is efficient and the customers are delivered high quality products.

Sourcing – This involves selection of the right supplier who provides for the manufacturing of the firm's product. Multiple suppliers can be selected and these can determined based on factors such as pricing, transportation, payment processes and quality of raw materials. Also deals with receiving of the product, verifying them and delivering at the right station for processing.

Making – This is the process where actual processing of raw materials and manufacturing of the firm's product takes place. Hence important factors such as scheduling of processes, managing inventory and informing to order more and managing of the equipment are taken care of.

Delivering – This is the process which takes care of send out orders. Management of warehouses, scheduling carrier departures and development of network of efficient deliveries comes in this section.

Returning – This involves receiving worn-out and defective products from the customers. This process also takes care of after-sales services such as repair or servicing to the customer.

We would be looking into the "Planning" part of the processes. Inventory management for the firm comes under planning. Inventory management is done by setting up a good ordering model which suits best for the system. Proper planning has to be done in order to avoid unnecessary losses in over stocking which is cost involved in storing excess inventory. As Ganeshan and Harrison (1995) said, these costs can be very high. Whereas under stocking leads to pending orders and ultimately loss of customers.

3.2. Inventory Management –

As said earlier, inventory management is an important part of the planning process. As Jacobs and Chase (2011) said inventory is the stock of any item or resource used in an organization. Inventory management is set of rules used to determine when the stock should be replenished, what should be the order quantity and how much should be the safety stock. Maintaining inventory is an important aspect in the business sector.

Purpose of Inventory Management –

All the industries have to manage an efficient inventory control. The reason behind this is as follows

- Inventory management is done to maintain independence of all the operations. For example in assembly lines, producing or manufacturing the same product doesn't always take the same amount of time. Some products take shorter times whereas some products take longer times. In order to compensate these different times an effective inventory would not disrupt the process in any way.
- If demand is known then it is convenient to produce the exact number of parts. But this is not true. Maintaining enough inventory helps to manage this variations in demand.
- When an order for raw materials is placed, they are not available for a certain period of time. This time period is known as lead time. Having a safety stock helps in keeping the production line active during these lead times. Maintaining a safety stock is a part of inventory management.

Inventories exist at every stage of the supply chain as either raw material, semi-finished or finished goods. They can also be in-process between locations. Their primary purpose is to buffer against any uncertainty that might exist in the supply chain. Maintaining inventory involves various costs affecting the goods. If inventory is not managed properly these cost can be very high ranging from 20% to 40% of the products original value (Ganeshan and Harrison 1995). This is very much undesirable.

Various inventory costs involved in inventory management are holding costs, setup costs, ordering costs and shortage costs (Jacobs and Chase 2011).

Holding Costs – These come in when excess inventory is stored. This excess inventory can also be the safety stocks. Holding costs mainly involves costs for storage units, handling, insurance, breakage, taxes, and depreciation. If the holding costs are high then the orders are placed more often and vice versa.

Setup Costs – When different products are produced, a change is setup of the equipment is required. Also different raw materials and a specific arrangement of equipment lead to down time. Due to this excess raw material or unfinished products are sent back to storage. This results in increasing in inventory cost. These costs are called as setup costs.

Ordering Costs – These costs mainly refer to clerical costs in preparing the purchase order. This involves going through to the inventory at hand and calculating the ordering number for raw materials.

Shortage Costs – When there are stock-outs, the whole production line is stalled. This happens even if there are raw materials for other processes but these processes cannot proceed because of shortage of a particular raw material in preceding processes. Hence the system suffers from a down time. Costs associated here are wages for the people working in the unit and resources costs (such as electricity). This also results not being able to fulfill orders on time resulting in backlogs.

3.3. Inventory Models –

In order to correctly manage these costs, there has to be a perfect balance between maintaining stocks and ordering the correct quantity. In order to maintain this good balance efficient ordering systems need to be set up. Every manufacturer is confronted with the issues of finding the most economical order quantity systems. As mentioned by Jacobs and Chase (2011) there two basic types of ordering systems. A single period inventory model and Multi period inventory system.

3.3.1. Single Period Inventory Model –

A single period inventory model is also commonly as the newsvendor model. For example, let us consider a newspaper vendor. A vendor has to order just about right quantity to fulfill his order for that day. At the end of the day if there are newspapers left to sell then money invested in that is a loss. So if the quantity is large then it’s a major loss for the vendor. On the other hand if the vendor is short of newspapers before the day ends then then it’s a loss in his profits.

3.3.2. Multiperiod Inventory Model –

There are two main types of multiperiod inventory systems. Economic Ordering Quantity model (EOQ or Q-model) and Fixed-Time Ordering Quantity model (periodic system or P-model).

Economic Order Quantity –

Economic ordering quantity model mainly deals with fixing the order to a particular point. A re-order point is decided. When the stock levels reach the re-order point, order is placed to replenish the stock levels. This system is desirable when average inventory is expensive to maintain. Since fixed order system assumes tracking inventory on hand, less inventory is possible to maintain hence cutting holding costs.

Since the inventory is continuously monitored as soon as the stock levels reach the re-order point, an order is placed. Re-order point is based on the daily demand for the product and the lead time on it when order is placed.

Fixed-Time Order Model –

Fixed-Time period models are the models where orders are placed periodically, weekly or monthly. Like previously seen model, this model has different ordering quantity every time. This model generates order quantity based on the incoming customer demand. This model is used when large amount of inventories are to be maintained against stock out. Placing orders periodically is effective when vendors make routine visits to customers.

Orders are placed at regular intervals (T) with a lead time of L. The quantity, q, to order is

$$\text{Order Quantity} = (\text{Average Demand over the vulnerable time}) + (\text{Safety Stock}) - (\text{Inventory available})$$

$$q = d(T+L) + z\,\sigma_{(T+L)} - I \qquad \text{(Equation 1) (Jacobs and Chase 2011)}$$

q	= Order Quantity
d	= Average Daily Demand
T	= Number of days between review
L	= Lead Time
z	= Number of standard deviations for a specified service probability (defined in-stock probability)
$\sigma_{(T+L)}$	= Standard deviation of demand over the review and lead time
I	= Current Inventory level

A very large order might deplete the stocks earlier than expected which is a major disadvantage. Since inventory is counted only during the review period this can go unnoticed and becomes a major disadvantage. Due to this the right levels of safety stocks need to be maintained.

4. Project –

4.1. Simulation Setup –

Simulation done for the observations is designed in Microsoft EXCEL. Supply chain for the simulation consists of five individuals. These individuals are Customer, Retailer, Wholesaler, Distributor and a Manufacturer. Flow of materials starts from the manufacturer and ends at the customer. Manufacturer sends his finished product to the distributor who sends to wholesaler who sends it to the distributor who sends it to the retailer and finally to the customer. Flow of orders starts with the customer and ends at the manufacturer. Hence flow of materials and flow of orders is in opposite directions. Since we are observing fixed time ordering strategies orders are placed on weekly basis.

Assumptions made for the simulation are as follows

i. Manufacturer has infinite inventory. Manufacturer always has parts ready to ship to distributor when order is placed.
ii. Lead time for all the orders is one week.
iii. Average weekly demand is considered as 100 and 20 as weekly standard deviation.
iv. Starting inventory for all the individuals in the supply chain is assumed to be 100.

Customer - Supplier Relationship:

A customer-retailer relationship can be defined as a link in the supply chain where the individual who orders is the customer and the individual who receives the order is the supplier. For the simulation the first link is the customer and its supplier is the retailer. Second link is Retailer and wholesaler where retailer is the customer and wholesaler is the supplier. Third link is wholesaler and distributor where wholesaler is customer and distributor is the supplier. And finally forth link is distributor and manufacturer where distributor is the customer and manufacturer is the supplier.

In the simulation, customer is starting link in the supply when placing orders. Customer order for the simulation is decided by the function. The function is as follows.

Customer Demand = MAX (INT (NORMINV (RAND ( ), V3, V9)), 0)

V3 = Average weekly demand (=100)

V9 = Weekly Standard Deviation (=20)

This demand is recognized by the retailer and based on stock available and backlog from previous week parts are delivered to the customer. Number of parts to be delivered to the customer is decided by the following formula.

$$\text{Delivery to Customer in week 1} = \text{MIN (Retail stock in week 0, Customer Demand + Backlog)}$$

Week	Customer Demand	Del to customer	Retail Order	Ret Stock	Backlog	Retail held inv (1 week)
0				100	0	0
1	117	100	115	100	17	0
2	112	100	115	100	29	0
3	102	100	115	100	31	0
4	121	100	115	100	52	0
5	104	100	115	100	56	0
6	116	100	108	107	72	0
7	105	107	115	100	70	0
8	74	100	108	107	44	0
9	120	107	115	100	57	0
10	55	100	108	107	12	0
11	93	105	112	102	0	2
12	74	74	79	136	0	28
13	59	59	38	177	0	77
14	108	108	39	176	0	69
15	101	101	80	135	0	75

Fig.1 Customer - Retailer Relation in Simulation

Retail order is based on the ordering quantity equation (Equation 1).

In simulation,

Order Quantity for the Retailer for week 1 = MAX (0, V3*2 + NORMSINV (V5) * V13 - (E2+H2-C3))

Avg. Demand = V3*2
Safety Stock = NORMSINV ($V#5) * V13
Inventory Available = E2 + H2 + C3

Retailer stock is the number of parts available for the retailer to fulfill the customer's demand for that week. This number is determined after receiving previous week's order and parts available in inventory after fulfilling previous week's inventory. For example, retailer stock in week 1 is the number of parts available with the retailer to fulfill week 2's order by the customer. This is determined by the equation as follows.

Retailer Stock (Ret Stock) for week 1 = MAX (0, E2-C3+H2)

E2 = Retailers Stock in week 0
C3 = Customer Demand for week 1
H2 = Order shipped by the Wholesaler in week 0

Backlog is number of parts waiting to be send to the customer because enough parts were not available to fulfill the order. This number is determined by the difference between customer demand and available inventory to fulfill the order. Equation for backlog in week 1 is as follows.

Backlog = MAX (0, F2 + (B3 – C3))

F2 = Backlog for previous week i.e. week 0
B3 = Customer Demand for week 1
C3 = Number of parts delivered to customer in week 1 by the retailer

Next column in the simulation is the number of parts carried forward. Retailer held inventory is the number opposite that of backlog. Number of parts available in inventory after fulfilling a customer demand is this number. Hence for any week in the simulation either backlog or retailer held inventory will be zero. For week 1, the equation is as follows

Ret held inventory = MAX (0, E2 –C3)

E2 = Retail Stock in week 0
C3 = Customer demand for week 1

Retail Order	Ret Stock	Backlog	Retail held inv (1 week)	In route to Retail	Wholesaler Order	WS Stock	WS Backlog	Wholesaler Held inv (1 week)
	100	0	0	100		100	0	0
114	101	0	1	100	115	100	14	0
80	135	0	35	94	108	106	0	6
85	130	0	36	85	94	121	0	21
94	121	0	36	94	80	134	0	27
96	119	0	25	96	86	129	0	38
90	125	0	29	90	90	125	0	39
68	147	0	57	68	68	147	0	57
102	113	0	45	102	102	113	0	45
75	140	0	38	75	75	140	0	38
94	121	0	46	94	94	121	0	46
106	109	0	15	106	106	109	0	15
108	107	0	1	108	108	107	0	1
106	109	0	1	106	113	102	0	1
106	109	0	3	102	109	106	4	0
113	102	0	0	106	114	101	11	0

Fig 2 Retailer and Wholesaler Relationship in the simulation

Relation between the retailer - wholesaler and wholesaler – distributor is similar to that of customer and retailer. Snapshot of the retailer – wholesaler relation can be seen as in fig.2. Similar columns are made for wholesaler - distributor relation. This is so because between retailer and wholesaler, retailer is the customer for the wholesaler. Similarly between wholesaler and distributor, wholesaler is distributor's customer.

Other parameters	
weekly demand	100
In stock Prob	
Retail	0.88
Wholesaler	0.9
Distributor	0.9
Weekly Stand Dev	
Retail	20
Wholesaler	20
Distributor	20
Tot Stand Dev	
Retail	28.28427
Wholesaler	28.28427
Distributor	28.28427

Fig. 3 Parameters for the Simulation

Parameters of the simulation (fig. 3) can be altered by changing weekly demand (V3), retail standard deviation (V9), wholesaler standard deviation (V10) and distributor standard deviation (V11). Total standard deviation is calculated because variation mentioned is the weekly based. Total standard deviation represents variation occurred for the time period of (T+L).

Tot Stand Dev. = SQRT(2*V10^2)

These are the parameters that basically control the whole simulation. For the simulation important parameter of control was defined in-stock probability. Actual in-Stock probabilities are the probabilities that show the percent of times the individual in the system is in-stock to fulfill customer's demand. Hence for the simulation in-stock probability for retailer is calculated as follows.

Actual In-Stock Probability = COUNTIF (F3:F10002, 0) / 10000

Column F in simulation = Backlog for retailer.

As seen above for the retailer, in-stock probability for wholesaler and distributor are calculated in similar way.

4.2. Simulation Analysis –

In the earlier section, we saw how the simulation is set up. In order to observe the interactive of in-stock probabilities for fixed time ordering strategies, comparison between different defined in-stock probabilities carried out. In the simulation as seen earlier, there are three main links i.e. retailer, wholesaler and distributor. Comparison between in-stock probabilities is carried out by keeping two individuals out of three constant and varying the third individual. For example, wholesaler and distributor are kept constant and retailer in-stock probability is kept variable. Table 1 show the simulation carried out.

RETAILER, WHOLESALER, DISTRIBUTOR		
Retailer, 0.9, 0.9	0.9, Wholesaler, 0.9	0.9, 0.9, Distributor
Retailer, 0.9, 0.8	0.9, Wholesaler, 0.8	0.9, 0.8,, Distributor
Retailer, 0.9, 0.7	0.9, Wholesaler, 0.7	0.9, 0.7, Distributor
Retailer, 0.8, 0.9	0.8, Wholesaler, 0.9	0.8, 0.9, Distributor
Retailer, 0.8, 0.8	0.8, Wholesaler, 0.8	0.8, 0.8, Distributor
Retailer, 0.8, 0.7	0.8, Wholesaler, 0.7	0.8, 0.7, Distributor
Retailer, 0.7, 0.9	0.7, Wholesaler, 0.9	0.7, 0.8, Distributor
Retailer, 0.7, 0.8	0.7, Wholesaler, 0.8	0.7, 0.8, Distributor
Retailer, 0.7, 0.7	0.7, Wholesaler, 0.7	0.7, 0.7, Distributor

Table 1 Simulation Parameters for Defined In-Stock Probability

As seen above in the table 18 simulations were carried out. For “Retailer, 0.9, 0.9”, wholesaler and distributor in-stock value is set for 0.9 i.e. 90% probability for having just enough inventory to fulfill in the next incoming order. Retailer’s in-stock value here is variable. The variable value changes from 0.9 to 0.6 with the difference of 0.02. Hence the variable value used for every simulation is (0.90, 0.88, 0.86, 0.84, 0.82, 0.80, 0.78, 0.76, 0.74, 0.72, 0.70, 0.68, 0.66, 0.64, 0.62 and 0.60). Every instance in the simulation runs for 10,000 instances which is 10000 weeks. The simulation was first tested at 2500 weeks. It was observed that the values obtained for actual in-stock probability had a lot of variation. Resulting actual in-stock probabilities showed variation of approximately 0.1 which is not at all desirable. Hence it was tested again for 10000 instances which showed very less variation which could be neglected. After increasing the number of instances or the number of weeks for the simulation variation in values of actual in-stock probability reduced to 0.03. This variation is not very high and is acceptable.

Other parameters	
weekly demand	100
In stock Prob	
Retail	0.88
Wholesaler	0.9
Distributor	0.9
Weekly Stand Dev	
Retail	20
Wholesaler	20
Distributor	20
Tot Stand Dev	
Retail	28.28427
Wholesaler	28.28427
Distributor	28.28427

Firm	In stock prob
Retailer	0.8649
Wholesaler	0.9991
Distributor	0.9990

Fig. 4 Inserting In-Stock Probabilities and the Results Obtained

Corresponding defined in-stock probabilities are inserted the red box as shown in the fig. 4. If retailer in-stock probability is kept variable then all the different in-stock probability values are inserted in the Retail box one after the other. Since wholesaler and distributor value are constant these values are not changed till all the values for the retailer are inserted. Fig. 6 shows an instance for variable retailer in-stock value and constant wholesaler and distributor in-stock values. In this instance the retailer in-stock probability is at 0.88 and wholesaler and distributor in-stock probability is kept constant at 0.90.

Results for the set of inserted values are displayed in the black box alongside. These values obtained are the actual in-stock probability for that particular instance. For the instance in fig. 4, actual in-stock probability for the retailer, wholesaler and distributor are 0.8649, 0.9991 and 0.9990 respectively.

For every simulation mentioned in table 1 all the values ranging from 0.90 to 0.60 are run. This is explained in the next section.

5. Observations & Results –

The simulation is run for 10,000 weeks for all the settings as mentioned in table 1. Values for the safety stock are entered from 0.90 to 0.60 at interval of 0.02 for every variable safety stock.

5.1. Variable Retailer In-stock Probabilities –

Retail		Wholesaler		Distributor	
Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob
0.9	0.8905	**0.9**	0.9994	**0.9**	0.9993
0.88	0.8636	**0.9**	0.9992	**0.9**	0.9991
0.86	0.8453	**0.9**	0.9996	**0.9**	0.9994
0.84	0.8223	**0.9**	0.9993	**0.9**	0.999
0.82	0.7806	**0.9**	0.9991	**0.9**	0.999
0.8	0.7482	**0.9**	0.9989	**0.9**	0.9987
0.78	0.6991	**0.9**	0.9989	**0.9**	0.9988
0.76	0.6695	**0.9**	0.9992	**0.9**	0.9991
0.74	0.6505	**0.9**	0.9996	**0.9**	0.9993
0.72	0.5847	**0.9**	0.9992	**0.9**	0.9988
0.7	0.5497	**0.9**	0.9994	**0.9**	0.9987
0.68	0.5454	**0.9**	0.9989	**0.9**	0.9989
0.66	0.4728	**0.9**	0.9992	**0.9**	0.9991
0.64	0.4479	**0.9**	0.9989	**0.9**	0.9987
0.62	0.3661	**0.9**	0.9995	**0.9**	0.9995
0.6	0.3776	**0.9**	0.9996	**0.9**	0.999

Table 2 (Retailer, 0.9, 0.9)

Output of the first simulation is as shown in table 2. The first simulation performed had fixed values for wholesaler and distributor as 0.9 and the retailer values were varied from 0.90 to 0.60. From table 2 we can see that the actual in-stock probability for the wholesaler and distributor is higher than their defined in-stock probability whereas actual in-stock probability for the retailer tries to stay close to the defined in-stock probability as the values change. We can also see that as the retailer value drops, the difference between the defined in-stock probability and actual in-stock probability increases.

The next simulation was for the setting of (Retailer, 0.9, 0.8). Simulation output for this setting is as shown in table 3. Retailer shows similar trend to the previous setting. In distributor’s output, it can be seen that till the defined in-stock probability for distributor is equal to or greater than retailer’s defined in-stock probability, actual in-stock probability is less than 0.8. The value increases as the retailer defined in-stock probability reduces. This effect of distributor's actual in-stock probability can be seen on wholesaler's actual in-stock probability. But the wholesaler is not affected as much as the distributor is in this case.

Retail		Wholesaler		Distributor	
Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob
0.9	0.88	**0.9**	0.9014	**0.8**	0.6715
0.88	0.8596	**0.9**	0.917	**0.8**	0.6846
0.86	0.8358	**0.9**	0.9315	**0.8**	0.7048
0.84	0.8201	**0.9**	0.969	**0.8**	0.7243
0.82	0.7827	**0.9**	0.9921	**0.8**	0.7423
0.8	0.7496	**0.9**	0.9988	**0.8**	0.9986
0.78	0.7063	**0.9**	0.9974	**0.8**	0.9961
0.76	0.6755	**0.9**	0.9991	**0.8**	0.999
0.74	0.6583	**0.9**	0.9987	**0.8**	0.9984
0.72	0.6047	**0.9**	0.9985	**0.8**	0.9972
0.7	0.5376	**0.9**	0.9989	**0.8**	0.9983
0.68	0.528	**0.9**	0.9997	**0.8**	0.9992
0.66	0.4844	**0.9**	0.9987	**0.8**	0.9987
0.64	0.4422	**0.9**	0.9989	**0.8**	0.9975
0.62	0.3834	**0.9**	0.9991	**0.8**	0.9981
0.6	0.3458	**0.9**	0.9985	**0.8**	0.9991

Table 3 (Retailer, 0.9, 0.8)

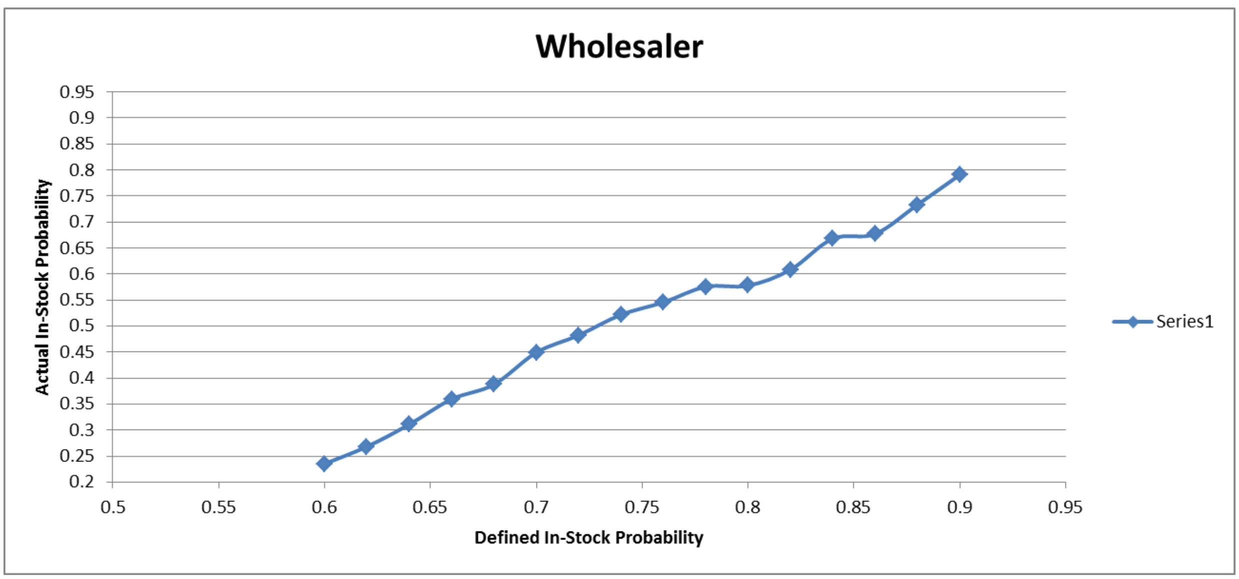
This phenomenon can be verified in simulations performed for (Retailer, 0.9, 0.7), (Retailer, 0.8, 0.9), (Retailer, 0.8, 0.8), (Retailer, 0.8, 0.7), (Retailer, 0.7, 0.9), (Retailer, 0.7, 0.8) and (Retailer, 0.7, 0.7). Hence it can be said that when customer in-stock probability is less than the supplier in-stock probability than the supplier would not have stock out chances.

5.2. Variable Wholesaler In-Stock Probabilities –

For the second set of simulations, retailer and the distributor have their in-stock probabilities constant and wholesaler's in-stock probabilities are variable. A similar phenomenon is seen when the retailer value is set to 0.9. This can be seen in Table 4. In table 4, if we consider retailer as customer and wholesaler as supplier then the earlier statement stands true. Supplier's actual in-stock probability for the customers demand is lower than the defined in-stock probability. Similarly if we consider wholesaler as customer and distributor its supplier, we can see that till wholesaler's defined in-stock probability is higher than distributor's in-stock probability, distributor's stock out chances are higher. As soon as the wholesaler's defined in-stock probability is lower than distributor's defined in-stock probability, distributor does not have stock out chances. A graph is plotted for wholesaler's defined in-stock probability vs. actual in-stock probability. It is as seen in Graph 1. This is true for (0.9, Wholesaler, 0.9) and (0.9, wholesaler, 0.8)

Retail		Wholesaler		Distributor	
Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob
0.9	0.8625	**0.9**	0.7906	**0.7**	0.4345
0.9	0.8567	**0.88**	0.7332	**0.7**	0.4412
0.9	0.8426	**0.86**	0.6771	**0.7**	0.4265
0.9	0.8471	**0.84**	0.668	**0.7**	0.4445
0.9	0.8371	**0.82**	0.6083	**0.7**	0.4179
0.9	0.8239	**0.8**	0.5778	**0.7**	0.4265
0.9	0.8293	**0.78**	0.5757	**0.7**	0.4559
0.9	0.8361	**0.76**	0.5457	**0.7**	0.4522
0.9	0.8317	**0.74**	0.5219	**0.7**	0.4583
0.9	0.8153	**0.72**	0.4824	**0.7**	0.4522
0.9	0.8175	**0.7**	0.4493	**0.7**	0.9981
0.9	0.7967	**0.68**	0.3878	**0.7**	0.9989
0.9	0.7772	**0.66**	0.3596	**0.7**	0.999
0.9	0.7438	**0.64**	0.3109	**0.7**	0.9991
0.9	0.7273	**0.62**	0.2684	**0.7**	0.9987
0.9	0.7125	**0.6**	0.2353	**0.7**	0.999

Table 4 (0.9, Wholesaler, 0.7)

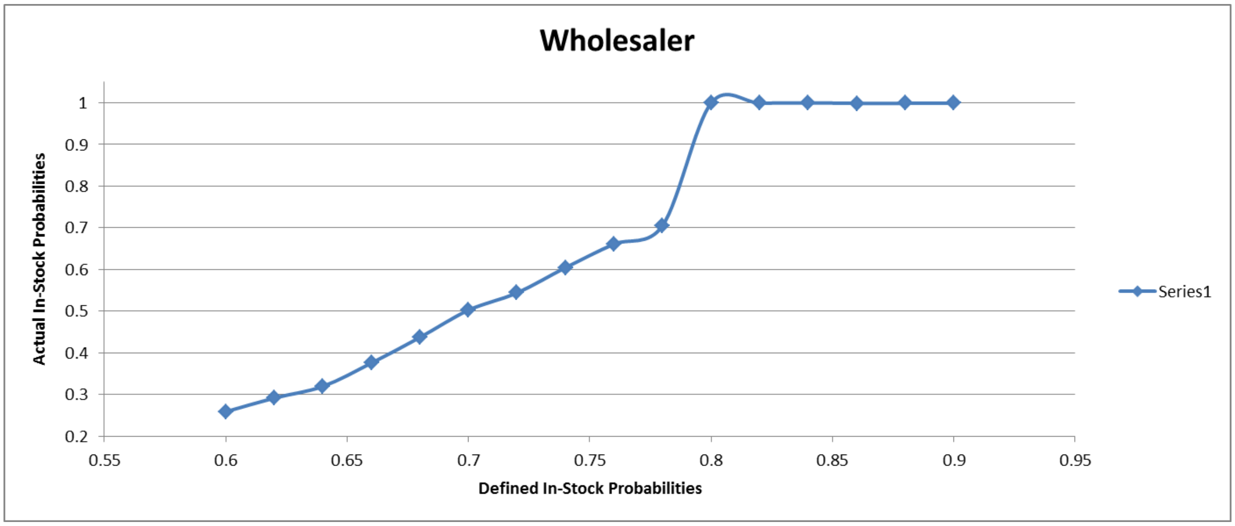


Graph 1 (0.9, Wholesaler, 0.7)

When the retailer defined in-stock probability is set to a lower value as 0.8 or 0.7, wholesaler behaves in a completely different way. This can be seen in table 5 and graph 2.

Retail		Wholesaler		Distributor	
Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob
0.8	0.7464	**0.9**	0.999	**0.9**	0.99
0.8	0.7573	**0.88**	0.9988	**0.9**	0.99
0.8	0.7399	**0.86**	0.9987	**0.9**	0.99
0.8	0.7491	**0.84**	0.9998	**0.9**	0.99
0.8	0.7393	**0.82**	0.9992	**0.9**	0.99
0.8	0.7438	**0.8**	0.9996	**0.9**	0.99
0.8	0.7463	**0.78**	0.7055	**0.9**	0.99
0.8	0.7452	**0.76**	0.661	**0.9**	0.99
0.8	0.7229	**0.74**	0.6046	**0.9**	0.99
0.8	0.7092	**0.72**	0.5439	**0.9**	0.99
0.8	0.7041	**0.7**	0.5024	**0.9**	0.99
0.8	0.6771	**0.68**	0.4372	**0.9**	0.99
0.8	0.6524	**0.66**	0.3756	**0.9**	0.99
0.8	0.6247	**0.64**	0.3196	**0.9**	0.99
0.8	0.6226	**0.62**	0.2916	**0.9**	0.99
0.8	0.6101	**0.6**	0.2588	**0.9**	0.99

Table 5 (0.8, Wholesaler, 0.9)



Graph 2 (0.8, Wholesaler, 0.9)

In this case, it is seen that the wholesaler maintains no stock out chance till the in-stock probability goes below retailer's in-stock probability. In the customer-supplier relationship, if the supplier maintains its in-stock probability a little higher than its customer, a supplier would not run out of inventory to fulfill customer demands. This factor completely ignores the effect of wholesaler's such behavior on the customer's inventory control. The effect noticed on the retailers is very small. Hence defined and actual in-stock probabilities are almost similar till wholesalers show a higher actual in-stock probability.

Graph 1 shows a linear increase in in-stock probability of the wholesaler whereas graph 2 shows a linear increase in the beginning and then a sudden change which then stays constant. This suggests that the wholesaler's defined in-stock probability is higher than its customer i.e. the retailer's in-stock probability. Hence it doesn't matter what is defined in-stock probability for the wholesaler in that range. For the same, if the wholesaler is considered as the customer and distributor as the supplier then it follows the same phenomenon as followed by (Retailer, 0.9, 0.8).

Such behavior between the retailer-wholesaler-distributor stays true for (0.8, Wholesaler, 0.8), (0.8, Wholesaler, 0.7), (0.7, Wholesaler, 0.9), (0.7, Wholesaler, 0.8) and (0.7, Wholesaler, 0.7).

5.3. Variable Distributor In-Stock Probability

In the next set of simulation, retailer and wholesaler have their in-stock probabilities constant and distributor has variable in-stock probabilities. In variable distributor in-stock probabilities except (0.9, 0.9, Distributor) all show similar phenomenon as seen in the earlier section 5.3.

Retail		Wholesaler		Distributor	
Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob	Defined In-Stock Prob	Actual In-Stock Prob
0.9	0.8989	**0.9**	0.9996	**0.9**	0.9995
0.9	0.894	**0.9**	0.9698	**0.88**	0.8648
0.9	0.8948	**0.9**	0.9562	**0.86**	0.8207
0.9	0.8882	**0.9**	0.946	**0.84**	0.7821
0.9	0.8869	**0.9**	0.9267	**0.82**	0.7239
0.9	0.8805	**0.9**	0.9094	**0.8**	0.6846
0.9	0.8819	**0.9**	0.8929	**0.78**	0.6316
0.9	0.8704	**0.9**	0.8644	**0.76**	0.5802
0.9	0.8737	**0.9**	0.8466	**0.74**	0.5378
0.9	0.8731	**0.9**	0.8353	**0.72**	0.5009
0.9	0.8669	**0.9**	0.8088	**0.7**	0.4577
0.9	0.8506	**0.9**	0.7543	**0.68**	0.3754
0.9	0.8544	**0.9**	0.7487	**0.66**	0.3593
0.9	0.8191	**0.9**	0.6856	**0.64**	0.3003
0.9	0.8237	**0.9**	0.6524	**0.62**	0.2429
0.9	0.8143	**0.9**	0.6297	**0.6**	0.2235

Table 6 (0.9, 0.9, Distributor)

For this particular set of in-stock probabilities, the system works as discussed in section 5.1. If wholesaler is the customer then distributor is the supplier. According to the customer-supplier relationship, in-stock probability of the customer is higher than the supplier hence the distributor shows lower actual in-stock probabilities. Due to this the customer i.e. the wholesaler suffers from lower actual in-stock probabilities. Since wholesaler suffers from lower in-stock probabilities, effect is transferred to the retailer. Hence as seen in table 6, we can see lower actual in-stock probabilities compared to their respective defined in-stock probabilities.

6. Conclusion –

In brief, the main goal of this project is to understand the interactive effect of different in-stock probabilities in a periodic ordering strategy. By running the simulation on different set of in-stock probabilities different types of behaviors of the whole supply chain system was observed. Simulation involved many controlled variables. But even then the results obtained can be used for practical supply chains in order to understand and improve the industries ordering system following fixed time ordering policy.

When retailer's in-stock probability were variable it was noticed that if the customer ordering to a supplier has higher in-stock probability than its supplier, then it is likely that the supplier would not always be able to fulfill the demand. In practical application this can be used to avoid own stock out possibilities.

When wholesaler's in-stock probability was variable it was noticed that when for a particular range of defined in-stock probability chances of not being able to fulfill order are very negligible. This can be used in the practical supply chain to design own ordering policies provided customer's ordering policy is known. Since this gives a range for defined in-stock probability, feasible in-stock probability can be selected in order to avoid excess ordering which in turn save a lot of funds in ordering costs, holding costs and inventory costs.

When distributor has variable in-stock probability, being at the beginning of the material flow in the supply chain, extreme effects are noticed. When distributor has higher in-stock probability than either wholesaler or the retailer or even both, distributor has negligible stock out chances. But when the in-stock probability is lower than both retailer and wholesaler, distributor experiences major stock out possibilities than anticipated. In this case it was observed that actual in-stock probabilities were as low as 60% then the defined in-stock probability. This can cause major bottle neck for the whole supply chain which affects the later links in the supply chain. Depending on the parameters, variable distributor defined in-stock probability affects the retailer's actual in-stock probability. It always ends up being lower than the defined in-stock probability but it maintains a certain range until distributor has major stock out issues.

Hence it can be said that based on these results many inventory related issues can be looked at while designing or improving a system. Based on certain data obtained from customers and suppliers can help in understanding possible problems a firm can run into while planning ordering policies using fixed time order strategies. These issues can be monitored and prevented not only in external supply chain but also in internal supply chain. Hence avoiding many financial losses and potential customers.

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