

VALUE OF INFORMATION IN
VENDOR MANAGED SUPPLY CHAINS

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VALUE OF INFORMATION IN
VENDOR MANAGED SUPPLY CHAINS

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Thesis Abstract

Can Aytekin, “Value of Information in Vendor Managed Supply Chains”

Parallel to the advances in information technologies and growing awareness of information sharing in supply chains, vendor managed inventory systems have become an opportunity in supply chain management. In this study we analyze the value of information sharing in a vendor managed supply chain with three suppliers and one retailer. These three suppliers sell different but substitutable items to the retailer. With this motivation an agent based simulation model is generated to analyze the value of information sharing, by comparing a Retailer Managed Inventory system in which there is no information sharing with a Vendor Managed Inventory system with information sharing.

The generated models are used in the sensitivity analysis with the intention of observing the effect of holding cost, stock out cost, end item demand variability, lead times and order frequency on the value of information sharing. Finally, the models are embedded into a decision support system to be used for practical purposes by the supply chain managers.

Tez Özeti

Can Aytekin, “Tedarikçi Kontrollü Tedarik Zincirlerinde Enformasyonun Değeri”

Bilişim teknolojisindeki ilerlemeler ve tedarik zincirlendike enformasyon paylaşımının farkındalığının artması, tedarikçi kontrollü envanter yönetimi sistemlerinin tedarik zinciri yönetiminde bir fırsat olarak ön plana çıkmasını sağlamıştır. Bu çalışmada biz tedarikçi kontrollü, üç tedarikçi ve bir perakendeciden oluşan bir tedarik zincirince enformasyon paylaşımının değerini analiz ediyoruz. Bu üç tedarikçi farklı ancak birbirine ikame ürünleri perakendeciye tedarik ediyorlar. Bu amaçla, bir ajan tabanlı simülasyon modeli geliştirilmiştir ve bu model kullanılarak enformasyon paylaşımının değeri, perakendeci kontrollü envanter yönetiminin kullanıldığı ve enformasyon paylaşımı olmayan bir sistem ile tedarikçi kontrollü envanter yönetiminin kullanıldığı ve enformasyon paylaşımı olan bir sistemin karşılaştırılması yoluyla ölçülmektedir.

Oluşturulan modeller duyarlık analizinde kullanılarak, stokta tutma maliyeti, stokta bulunmama maliyeti, nihai ürün talep değişkenliği, teslimat süresi ve sipariş verme sıklığının enformasyon paylaşımının değeri üzerindeki etkileri ölçülmektedir. Son olarak, modeller bir karar destek sisteminin içine yerleştirilmiş ve tedarik inciri yöneticilerinin uygulamada kullanabilmesi için hazırlanmıştır.

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CHAPTER 1: INTRODUCTION

In today's competitive business environment, supply chains and their management are very critical issues for organizations. Organizations try to increase their profit in every way possible, and supply chain management is one of the most significant areas in which organizations can differentiate themselves from their peers. Thus they keep examining and applying various structures and arrangements to find out which type of coordination fits better to their specific supply chain.

There are numerous business models to choose from regarding supply chain management. In this study the focus will be on Retailer Managed Inventory (RMI) and Vendor Managed Inventory (VMI) systems.

RMI is a rather traditional approach compared to VMI. In RMI retailer has the responsibility of his own inventory and orders. However in VMI, the supplier makes the decisions regarding the orders of the retailer, and also carries the liability of inventory costs of the retailer. VMI system requires the retailer to cooperate by sharing demand information in order to succeed.

Information sharing consists of every possible piece of data being shared by the supply chains partners. The extent of this information can range from a simple order notice to sharing the Point of Sale (POS) data with the upstream members of the supply chain.

Although the sole purpose of information sharing is to add value to the supply chain it does not always lead to increased profits. Thus the value of the information

sharing has been of interest to both the researchers and practitioners. As one can imagine, measuring the value of information is not a simple task in the real world. Supply chains are too complex to observe every little bit of detail and the effect of every single decision. Researchers attempt to see the impact of information sharing on supply chains by making assumptions and extrapolating through the data gained from working on less complicated supply chains.

The primary aim of this thesis is to measure the value of information in a supply chain in which there is competition among different brands, and to decide upon the strategic appropriateness of an RMI or a VMI system. There are three suppliers, each supplying a different brand of an item and one retailer that sells items of all these suppliers in our supply chain. Without loss of generality, we might assume that these items are different brands of printers that can be used as partial substitutes to each other in an IT store. A customer willing to purchase a certain brand of a printer might choose to buy a different brand if the preferred one is out of stock. Comprehending how value of information is conceived in a VMI system in which competition exists among different brands is an intriguing issue, since the sales quantities depend on the inventory positions of the competitor brands. The primary idea of this study is to measure the contribution of a VMI system where the demand information is shared with competing suppliers.

We propose a simulation tool which utilizes Agent-Based Methodology. We treat each of the parties of the supply chain as agents who can decide and react according to their predefined behavioral models. They can respond to environmental changes and adapt accordingly. By using Agent-Based Modeling, we expect to see the value of information sharing more accurately.

This simulation tool is designed to serve as a Decision Support System (DSS) for both practical and academical use. The tool will help users to compare RMI to VMI and observe which one would be a better fit for their own supply chain in question. Users of this tool can decide upon all the parameters, which will allow them to see the value of information with different initial conditions and make sensitivity analyses.

The thesis is structured as follows: Chapter 2 presents the studies conducted in the literature. Chapter 3 briefly explains ABM, the methodology that is used in this study. In chapter 4 our model is explained in detail. Chapter 5 presents the sensitivity analysis part of our simulation and in chapter 6 the results of the sensitivity analysis are discussed. The final chapter concludes the study and discusses the possible further improvements.

CHAPTER 2: LITERATURE REVIEW

Definition of Supply Chain and Supply Chain Collaboration

Supply chains are defined as “Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers” (Lee & Billington, 1992).

Administering and directing supply chains is called Supply Chain Management which is most commonly and thoroughly defined as “the efficient management of the end-to-end process, which starts with the design of the product or service and ends when it has been sold, consumed, and finally, discarded by the consumer” (Swaminthan & Tayur, 2003).

Supply chains are used to be considered as linear systems, in which raw material enters at one end and the finished good comes out at the other end (Keskinocak & Tayur, 2001). However, as Veermani, Joshi and Sharma claim, supply chains are nowadays dynamic and responsive networks, supporting different types of products such as standard, configurable or custom manufactured products (as cited in Keskinocak & Tayur, 2001). This dynamic structure of supply chains calls for different approaches, thus making the supply chain management a more crucial concern.

Collaboration of the supply chains keeps getting more and more important, leading to increased number of models for supply chain integration. These models mainly aim for efficient replenishment between all parties of the supply chain. A

common aspect of these models is that they intend to improve the material flow and supply chain performance, and they concentrate on information flow along the supply chain in order to accomplish these improvements (Vigtil, 2007). Angulo, Nachtmann and Waller (2004) argued that Automatic Replenishment Programs such as Continuous Replenishment Planning, Efficient Customer Response, Quick Response, and Vendor-Managed Inventory can be characterized as partnership schemes based on information sharing among the members of supply chain with the purpose of matching supply and demand effectively.

Matching supply and demand is a major concern in supply chains because of the bullwhip effect. Bullwhip effect is defined as “the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer, and distortion propagates upstream in an amplified form” (Lee, Padmanabhan & Whang, 1997). Bullwhip effect has grave consequences that disturb the operation of the supply chain. Higher variance causes the members of the supply chain to carry more safety stock thus making higher investment in stock, to increase their production capacity and to put up with augmented storage space. Bullwhip effect also causes very intense resource utilization in some periods and underutilization in subsequent periods (Croson & Donohue, 2003).

Information Sharing in Supply Chains

Information sharing is declared to be the most conventional solution for preventing bullwhip effect in the literature. Research by Chatfield, Kim, Harrison and Hayaa

(2004) supports that information sharing decelerates the bullwhip effect in the supply chain as we go up the supply chain since it allows the members in the upstream of the supply chain to plan according to the customer demands in advance . Croson and Donohue (2003) claim that Point of Sale (POS) data sharing can help members of the supply chain overcome the oscillation and its negative effects by letting them better understand the nature of the internal orders they receive.

The main reason behind the increased focus on information sharing is the advancements in the information technologies. These advancements allow the supply chain members to collaborate with their suppliers and customers by sharing essential information quickly and inexpensively (Cachon & Fisher, 2000). The information sharing that happens in real time has helped the supply chains in many ways such as inventory reduction, increased service levels and quick response to the variation in market conditions (Simchi-Levi & Zhao, 2004).

Along with the increased interest on information sharing, more and more business models have emerged for better management of supply chains as mentioned before. Different business models have different types of information sharing requirements in order to work efficiently. In the research of De Toni and Zamolo (2005), they have pointed out some of the information types that are shared in supply chains, some of these data are stock levels, incoming orders, POS data, delivery schedules, sales forecasts and promotions.

When the literature is examined thoroughly, it is clear that information sharing has been of great interest to researchers. There are several papers in the

literature which approach information sharing from different perspectives and attempt to discover the value of information as seen in Table 1.

Table 1 - Studies on Information Sharing in a Supply Chain

Author	Topic
Mishra and Raghunathan (2004)	Retailer- vs Vendor-Managed Inventory and Brand Competition
Huang and Iravani (2005)	Production Control Policies in Supply Chains with Selective-Information Sharing
Jain and Moinzadeh (2005)	A Supply Chain Model With Reverse Information Exchange
Ye and Farley (2006)	Information Sharing and Control in Homogenous and Heterogeneous Supply Networks under Different Market Conditions
Li, Lin, Wang and Yan (2006)	Enhancing Agility by Timely Sharing of Supply Information
Abuhilal, Rabadi and Souza-Poza (2006)	Supply Chain Inventory Control: A Comparison Among JIT, MRP and MRP With Information Sharing Using Simulation
Kim (2008)	Revisiting "Retailer- vs Vendor-Managed Inventory and Brand Competition"
Choudhury, Agarwal, Singh and Bandyopadhyay (2008)	Value of Information in a Capacitated Supply Chain

In these papers value of information sharing is examined with different methodologies. Analytical models and different types of simulations are developed in order to recognize the value of information sharing in supply chains. The value of information is analyzed in different business models and constraints, such as the existence of brand competition, capacity constraints and different market conditions. Some of these papers on the other hand are focused on different types of information sharing and some information sharing specifications. The consequences of using selective information sharing, reverse information exchange and timely information sharing on the value of information sharing are investigated.

Vendor Managed Inventory Systems

One of the most studied model among the supply chain management models is Vendor Managed Inventory (VMI) system which emerged in the early 1980s. Although many definitions has been suggested for VMI, the broadest definition for VMI is “a continuous process in which the vendor assumes responsibility for the management of customer’s inventory” (Sarpola, 2007). VMI is a system that requires information sharing between the members of the supply chain (Angulo, Nachtmann & Waller, 2004).

VMI systems allow the suppliers to decide upon replenishment schedule and determine their own production plan as long as supply chain meets agreed upon customer service level. This freedom helps suppliers to have stabilized production levels and lower transportation costs (Claassen, Van Weele & Van Raaij, 2008).

These advancements in suppliers' side allows the retailer to achieve a certain productivity level which is very difficult to attain on its own (Achabal, McIntyre, Smith & Kalyanam, 2000).

According to the literature benefits of the VMI can be summarized as (Angulo, Nachtmann & Waller, 2004; Waller, Johnson & Davis, 1999; Daugherty, Myers & Autry, 1999; Achabal, McIntyre, Smith & Kalyanam, 2000):

- Reduced transportation and set up costs,
- Reduced lead times and increased inventory turnovers,
- Reduced inventory stock outs,
- A more responsive replenishment system,
- Increased customer service levels,
- Decreased bullwhip effect in the supply chain as one moves upstream.

As attractive as these benefits may seem, they are not very easy to achieve. In an interview, carried out by Aichlmayr (2000), an executive in the supply chain management field has claimed that “out of 10 VMI implementations, three or four achieve great benefits. Three or four have some benefits, but not as much as anticipated, and two or three do not get any benefits.”.

The low rate of success suggests that there are some downsides to the VMI implementation as well as the upsides. These downsides are discussed in a study by Gustafsson and Norrman (as cited in Disney & Towill, 2003). They state that although VMI concept is rather easy to understand, getting adapted to the change of working procedures is a long process. The shift of responsibility from the retailer to the supplier is another significant change that takes some time to become accustomed

to. Integration of enterprise resource planning (ERP) systems might create more work than expected. The last downside mentioned is that in a certain business with short-term supplier relations might have huge difficulties in implementing VMI. Since VMI requires close relations and trust among the partners of VMI, in short-term supplier relations it is very challenging to establish this kind of relationship and confidence.

Low rate of success in VMI implementations has led the researchers to concentrate on the underlying success factors of VMI. There are various studies in the literature that have their focus on understanding and depicting these factors.

Barratt (2004) stresses the importance of the nature of the relation between the members of the supply chain and draw attention to several important points for the application of successful VMI systems. These points are: trust between members, common goals and objectives, openness, clear and frequent communication between parties, stable relationships, mutual interdependency, commitment and honesty.

Besides the importance of the nature of the relationships all through the supply chain, the quality of information is very essential as well. As mentioned before information sharing is a necessity for VMI implementation, however information might not always be as beneficial as it can be due to low quality of information, i.e., information needs to have some specifications and meet certain requirements in order to be a valuable asset for the VMI implementation.

First of all information should be shared in a timely manner, delays in the information can cause the supplier to have delays in analyzing the information and planning the replenishment, which would negate one of the most important benefits

of VMI, i.e., planning the replenishment ahead. Hence it is essential that retailers share the information with no or few delay. Information should also be accurate; inaccurate information will result in inaccurate forecasts leading to extra costs. Lastly information is expected to be reliable, adequate and complete, only then VMI can be successfully implemented by making good use of shared information (Claassen, Weele & Raajj, 2008; Angulo, Nachtmann & Waller, 2004).

Sarpola (2007) proposes six main components for evaluating and differentiating VMI systems. It is claimed that different combinations of the six elements for inventory location, distribution model, inventory level monitoring and demand visibility, role of information systems, replenishment decisions and inventory ownership forms different VMI systems. It is also suggested that the first two elements have a relationship, as well as the second and third two components.

First, the location of the inventory either being in a distributed manner in the customer's premises or being in a centralized manner in vendor's premises or third party location, requires the vendor to be more involved or not in the distribution process, because when the inventory is located close to the customer, vendor representatives and customer can have the kind of interaction that generates some benefits, but when there is no interaction between vendor representatives and customers due to the centralized inventory location, outsourcing the distribution activities becomes a better option.

Second, the relation between the inventory the role of information systems and level monitoring and demand visibility is very clear, when the inventory level and the demand information of the customer are shared with the vendor in real time, it is

expected that the role of information systems will be more essential for the VMI system to succeed.

Finally, the connection between the replenishment decisions and inventory ownership in VMI relation is shaped by the request of the vendor to be more independent in replenishment decisions as the inventory ownership is transferred from the customer to the vendor.

Different methodologies have been used in the literature for measuring the value of information in supply chains. Sahin and Robinson (2002) classify these methodologies as analytical models, simulation, case study, mathematical programming, and empirical analysis. They also claim that the enlarged problem scope due to more complex network structures and more realistic demand structures set off the shift from analytical models to simulation-based research.

CHAPTER 3: METHODOLOGY

Simulation models are widely used in the supply chain researches in order to analyze complex, dynamic and stochastic systems and to improve the quality of the decision making (Almeder, Preusser & Hart, 2009). A simulation based approach is better suited for evaluating the system performance in systems that operate under wide variety of conditions (Rosetti, Miman & Varghese, 2008).

In this study we use Agent based modeling (ABM) for simulating the supply chain system. ABM is a new analytical tool which enables the researchers to build models where individual entities and their interactions are represented directly (Gilbert 2008). The basic components of ABM there are the agents which interact with each other within an environment (Zhu, 2008).

Here, the environment is a virtual world which can vary from being a market environment in which goods are bought and sold, to a geographical environment of a region or a country. Thus ABM can be compatible with many different fields of research. Environment is almost as important as agent itself in ABM.

“An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future” (Franklin & Graesser, 1996). In another definition an agent is defined as: autonomous or semi-autonomous components that interact with each other and the environment according to a series of rules that define their movement, actions, decisions and interactions (Chatfield, Hayya & Harrison, 2007).

According to Wooldridge and Jennings (1995), agents have four important properties which should be emphasized:

- **Autonomy:** An agent is able to operate without direct interference. Thus both its actions and its internal state are in control of itself.
- **Reactivity:** Agents can recognize the environment and reacts appropriately by taking the variations and alterations in the environment into consideration.
- **Pro-activity:** An agent can act in such a way that, it can plan ahead and take actions directed by its own internal goals.
- **Sociability:** Agents are able to interact with each other using predefined common sociability rules.

These properties have aroused the interest of supply chain researchers, especially in the last decade, and researchers have started to introduce more and more supply chain simulation studies by using ABM methodology. Thierry, Thomas and Bel (2008) argued that the reason for this increased interest in ABM is that the use of ABM in supply chain simulation enables the researchers to represent and assess both the existing interactions between the entities and their behaviors.

Yuan, Liang and Zhang (2001) state that the actors of the supply chain and agents have several similarities, and stressed the following analogies between actors and agents summarized in Table 2.

Table 2 - Comparison of Actors in a Supply Chain and Agents in an ABM

Actors in a Supply Chain	Agents in an ABM
There are multiple actors in the supply chains, i.e., manufacturers, suppliers, distributors, retailers, customers.	An ABM simulation consists of multiple agents.
The actors have goals, means and abilities necessary for carrying out tasks and follow certain rules.	Agents have goals, abilities, roles, and they can also take complex decisions through their reasoning abilities.
The actors make their decisions by coordination and negotiation.	Agents have social capabilities and they perceive the environment and act accordingly.
Coordination between the actors is realized through informational and decisional interactions.	Coordination between the agents is accomplished by informational interaction with other agents.
An actor has access to incomplete information shared by the members of the supply chain.	An agent has incomplete information shared by message exchanges.
The actors can decompose their tasks and assign them to other actors.	Agents can hand over some of the tasks to other agents.
Actors can join or quit the supply chain due to its dynamic structure.	Agents can be added or removed from the simulation.

These analogies show that ABM can facilitate the simulation of supply chains not only by allowing the researchers to take into account the distributed nature of the supply chains and the non-linearity of the behavior, but also by letting them modify the environment, allow for the decision complexity and variety (Thierry et al., 2008), thus making ABM a good fit for supply chain researches.

CHAPTER 4: MODEL

We build our model in order to examine the results of both RMI and VMI models.

We try to measure the effect of different input parameters on the performance measures of our proposed supply chain.

We consider a three-echelon supply chain with three manufacturers, three distributors and only one retailer. These three manufacturers produce different brands of a certain product, say printers, and these three brands are substitutes for each other. We assume that each manufacturer supplies a certain distributor and each distributor supplies the retailer with that particular product. Consequently retailer has three different brands of product that it can offer to the customers. Here the retailer can be conceived as a store selling technological products, including 3 brands of printers.

Although we simulate a three-echelon supply chain, we are actually interested in the two-echelon system between the distributors and the retailer. The manufacturers are assumed to have large production capacity for implementation purposes. We ignore both the costs and the revenues that occur for the manufacturers and we use the manufacturer agents only for the orders that they send to the distributors. Therefore, we actually develop this simulation model with the intention of analyzing two-echelon supply chain with one retailer and three distributors of three different brands.

The retailer experiences demands which are stationary and stochastic. The daily demand follows a normal distribution for each printer brand. The three

distributors are the only sources of inventory for the retailer and each supplies a certain printer brand. The retailer may or may not give orders depending on the management policy of the supply chain. As it was mentioned before, this thesis aims to compare the RMI system with VMI system in order to assess and comprehend the strategic appropriateness of both business models in different conditions.

Both the manufacturers and the distributors experience certain lead times which are preset at the beginning of the simulation. They also have predetermined starting inventories, sales prices and order frequencies. All of these parameters can be modified so as to evaluate their effects on the resulting performances.

In this study, we assume we have a technological product, say printers to be specific, and set the parameters accordingly. However it should also be noted that the parameters can be adjusted and the simulation can be run with another set of parameters for different products of different natures.

Consumer behavior is a major part of this model. Consumers that come to the retailer buy their preferred item if it is available in the retailer, however if the retailer cannot provide the customer with their preferred item, they decide upon their next move according to a preset consumer decision probability matrix given in Figure 1.

		j			
i	A	1	2	3	k
	1	0.25	0.25	0.25	0.25
	2	0.25	0.25	0.25	0.25
	3	0.25	0.25	0.25	0.25

Figure 1 – Customer decision matrix

$$A_{ij} \begin{cases} i = j & P(\text{Waiting for product } i \mid \text{product } i \text{ is not found}) \\ i \neq j & P(\text{Choosing to buy product } j \mid \text{product } i \text{ is not found}) \end{cases}$$

$$A_{ik} = P(\text{Not buying anything} \mid \text{product } i \text{ is not found})$$

The need for decision probability matrix in this model emerged as a result of the complex consumer behavior under the existence of brand competition. Customers have to make a decision when they cannot find their preferred items. They can choose to wait for their preferred item to arrive, and come and try to get it in certain number of days defined as a simulation parameter, or they can choose to buy a substitute item of their choice, or they can quit the retailer without buying anything at all.

In a stock out situation, customers will not choose to wait more than once for the same product. In their second visit, if their preferred product is still not in the stock they choose between either quitting or asking for an alternative brand. The customer is satisfied if the alternative brand is already in stock, otherwise he quits or asks for the other alternative brand. If he cannot find the last alternative brand in the stock either, he has no option but to quit.

Through this decision probability matrix, the user of the simulation is able to classify consumers into segments, each of which can be defined and adjusted in accordance with the expected consumer segments for each different market or product type. Consumer can be segmented according to being loyal to a brand or not, and being in need of buying that particular product or not.

There can be up to 3 different consumer segments, the simulation also gives the user the chance to set the percentage of the each consumer segment among all

customers. Consequently the user is able to choose up to three different customer segments, define the characteristics of each segment by changing probability matrices and determine the percentage of each segment among all the potential customers.

As time steps go by, costs and revenues arise for each party of the supply chain. Costs include, purchasing costs, ordering costs, holding costs and stock out costs. These costs may belong to different parties of the supply chain according to the business model in effect. Stock out costs are different for each of the situations described above, that is quitting, waiting for the same product or replacing it with another brand.

In each time step following events occur:

- Item replenishment for Distributors and Retailer is done.
 - Orders are given (depending on the order frequency)
 - Ordering costs occur.
 - Inventory of the distributors and manufacturers are decreased as much as orders.
 - Orders arrive at the end of the lead times.
 - Inventory of the related parties is increased.
 - Purchasing costs occur.
- Customer – Retailer interactions.
 - Customers are created according to the number of the daily demand for each product.

- The customers who have chosen to wait in a previous time step are created.
 - Customers are sorted randomly to determine their order of arrival.
 - Customers arrive to the retailer one by one.
 - Customers buy their preferred product if available.
 - If their preferred product is not available then,
 - Customers randomly decide their next action according to the predefined percentages.
 - Quit completely and do not buying anything.
 - Wait and come back again after a preset time interval.
 - However the customer cannot choose to wait one more time if he faces a stock out in his second trial as well.
 - Replace their item with one of the other two products.

According to the the replace percentage matrix of that customer type.
 - Stock out costs occur.
 - Exit the system as a satisfied or an unsatisfied customer.
- Holding costs occur.
- End of the time step.

These aspects of the model mentioned above are unchanged in both of the business models, namely RMI and VMI. In the next subsections RMI and VMI policies will be explained.

Retailer Managed Inventory Model

RMI model is actually the traditional supply chain business model as given in Figure 2. In the RMI model the distributors have no knowledge of the demand experienced by the retailer, retailer places orders every n^{th} time step, where n is preset by the user of the simulation. Retailer places the orders according to the actual demand that it is occurring. Retailer uses moving average of the last 30 time step while ordering, and multiplies the average order amount by n , in order to have enough stock for the next n time step.

As mentioned before the distributors do not recognize the actual demand in the retailer, therefore while ordering they employ the orders of the retailers in the last 30 time steps instead of the demand itself. They also calculate the amount of their orders by using the moving average of the last 30 time steps.

Both the retailer and the distributors have their own storages that they keep their inventory in, and they share no information at all, except for the orders placed. If the distributor does not have enough stock in hand to fulfill an order, then they send all the products they have to the retailer, but the rest of the order is lost, in other words there is no backordering between the retailer and the distributor, which is meaningful in this scenario as it helps the brand competition to be further emphasized.

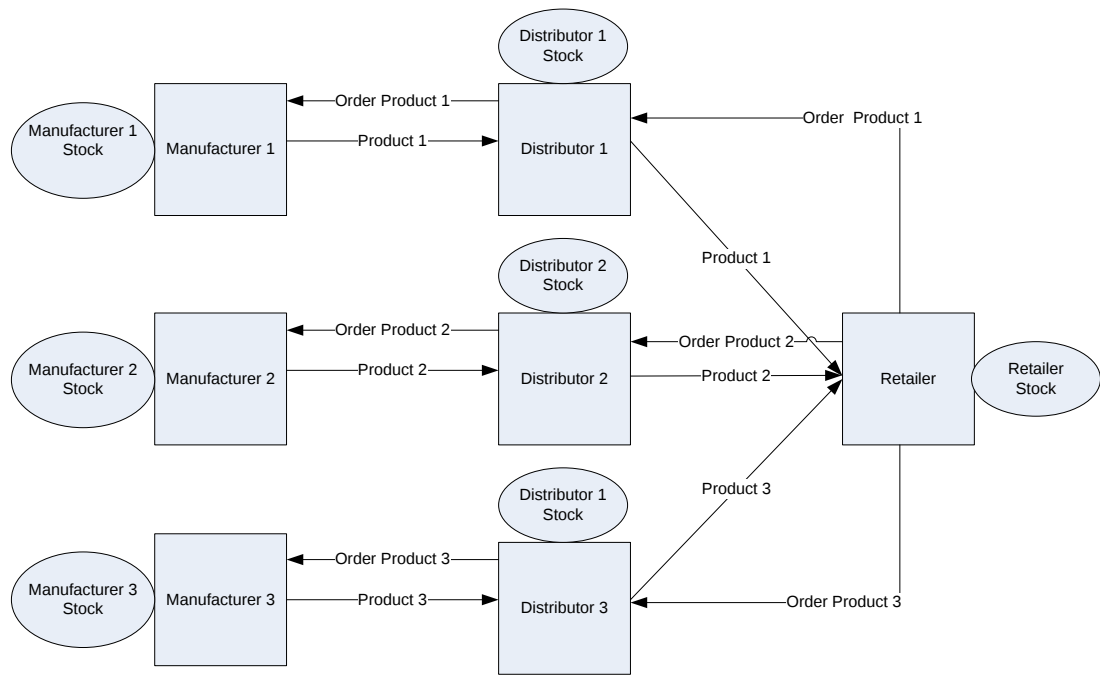


Figure 2 - RMI model

Vendor Managed Inventory Model

In the VMI model describes in Figure 3, the retailer does not give any orders at all; the management of the entire order decisions is accomplished by the distributors. The VMI agreements between the retailer and each distributor are assumed to be intact when the simulation begins.

Retailer shares the demand information with the distributors. It should be noted that each distributor can reach its own demand information, whereas the others are unreachable. Similar to the RMI model they again utilize a 30 time steps moving average method, but in this model distributors make use of the demand information shared by the retailer while placing their orders.

Distributors do not hold any inventory in their own storage, they send the orders they receive from the manufacturers directly to the retailer. In a way, they exploit the storage space of the retailer. However they also take charge of holding costs and ordering costs of the retailer concerning their own products along with the responsibility of the orders as well.

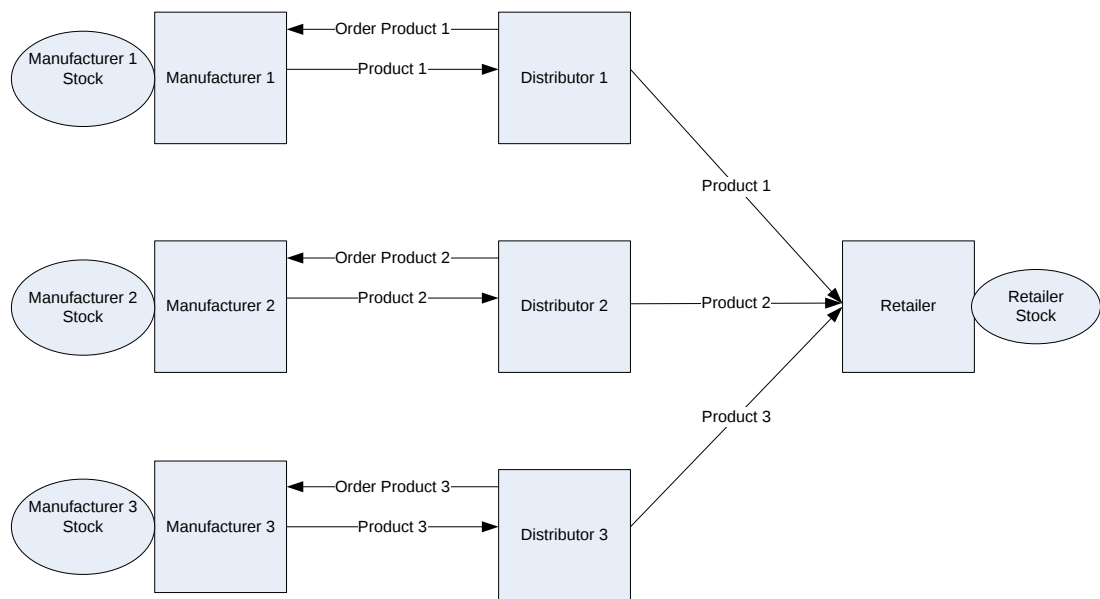


Figure 3 - VMI model

CHAPTER 5: SENSITIVITY ANALYSIS

In this study our primary aim is to analyze the value of information sharing in different scenarios through simulation experiments. We expect the value of information sharing to differ according to some input parameters, such as holding cost, stock out cost, demand variability, order frequency and lead times. With this motivation, we run the experiments for both our models, RMI and VMI, with different input parameters and compare them with our base case in order to analyze the change in the outputs hence the value of information sharing.

Our experiments are run for 250 time steps, and they are replicated 15 times each. We have 3 different scenarios and 11 different cases one of which being the base case that we run in all 3 scenarios giving us a total of 33 distinct settings. All the settings that we examine and the explanation for each case are shown in Table 3.

Table 3 – Settings for Sensitivity Analysis

Scenario No	No	Case	Holding Cost / Stock Out Cost	Demand Variability	Retailer Order Freq.	Distributor Order Freq.	Distributor Lead Time	Manufacturer Lead Time
Scenario 1 Identical Distributors Ordering Policy: Moving Average	1	Case 0 (Base Case)	Medium	Medium	Low	Medium	Low	Medium
	2	Case 1	High	Medium	Low	Medium	Low	Medium
	3	Case 2	Low	Medium	Low	Medium	Low	Medium
	4	Case 3	Medium	Low	Low	Medium	Low	Medium
	5	Case 4	Medium	High	Low	Medium	Low	Medium
	6	Case 5	Medium	Medium	High	Medium	Low	Medium
	7	Case 6	Medium	Medium	Low	High	Low	Medium
	8	Case 7	Medium	Medium	Low	Low	Low	Medium
	9	Case 8	Medium	Medium	Low	Medium	High	Medium
	10	Case 9	Medium	Medium	Low	Medium	Low	Low
	11	Case 10	Medium	Medium	Low	Medium	Low	High
Scenario 2 Non-Identical Distributors Ordering Policy: Moving Average	12	Case 0 (Base Case)	Medium	Medium	Low	Medium	Low	Medium
	13	Case 1	High	Medium	Low	Medium	Low	Medium
	14	Case 2	Low	Medium	Low	Medium	Low	Medium
	15	Case 3	Medium	Low	Low	Medium	Low	Medium
	16	Case 4	Medium	High	Low	Medium	Low	Medium
	17	Case 5	Medium	Medium	High	Medium	Low	Medium
	18	Case 6	Medium	Medium	Low	High	Low	Medium
	19	Case 7	Medium	Medium	Low	Low	Low	Medium
	20	Case 8	Medium	Medium	Low	Medium	High	Medium
	21	Case 9	Medium	Medium	Low	Medium	Low	Low
	22	Case 10	Medium	Medium	Low	Medium	Low	High
Scenario 3 Non-Identical Distributors Ordering Policy: Fixed Order Quantity	23	Case 0 (Base Case)	Medium	Medium	Low	Medium	Low	Medium
	24	Case 1	High	Medium	Low	Medium	Low	Medium
	25	Case 2	Low	Medium	Low	Medium	Low	Medium
	26	Case 3	Medium	Low	Low	Medium	Low	Medium
	27	Case 4	Medium	High	Low	Medium	Low	Medium
	28	Case 5	Medium	Medium	High	Medium	Low	Medium
	29	Case 6	Medium	Medium	Low	High	Low	Medium
	30	Case 7	Medium	Medium	Low	Low	Low	Medium
	31	Case 8	Medium	Medium	Low	Medium	High	Medium
	32	Case 9	Medium	Medium	Low	Medium	Low	Low
	33	Case 10	Medium	Medium	Low	Medium	Low	High

In our first scenario, the distributors are completely identical, their products face the same end demand and they have the same purchase and sales prices. Both the retailer and the distributors order by calculating the moving average of the last 30 time steps. Retailer employs the last 30 time steps demand, and the distributors utilize the last 30 time steps orders from retailers in the RMI model. In the VMI model the distributors

make use of the demand information and order in accordance with the last 30 time steps end demands, retailer does not give orders in VMI as mentioned before.

Our second scenario has the same ordering scheme as the first scenario; however in this scenario we have dissimilar distributors. The purchase price and the sales price of the distributors are different, all three products are still substitutable, then again we assume them to have different prices as a consequence of marketing policies such as brand image. The end demands of all three items are modified according to their sales prices, we use a linear demand curve to calculate the end demands of the products.

In the third scenario, we experiment with dissimilar distributors similar to the second scenario; however in this scenario the ordering policy is different than the first two scenarios. Instead of using moving average, fixed ordering policy is utilized. The retailer orders according to the mean of the demand without ever changing the order amount. Distributors still use the moving average in the RMI model since they have no access to the end product demand. In the VMI model the distributors use the fixed ordering policy as well as they can reach the demand information.

Input parameters for the base case of scenario 1, input parameters that are different in the base cases of scenario 2 and 3, and the input parameters that are modified for different cases are given in the Appendix-A.

As mentioned before, these cases are run in all three scenarios to examine the effect of these parameters on the outputs for both RMI and VMI models in each scenario. Although the results of different scenarios cannot be easily compared for certain outcomes, the comparison is still beneficial for developing some intuitions.

CHAPTER 6: RESULTS

The analysis and the comparison of the cases are mainly done according to the important performance measures of the supply chain. These performance measures are: the profit of the retailer, the profits of the distributors, the profit of the supply chain and the service level of the retailer; however we also examine some other performance measures such as various costs as well in order to better comprehend and explain the dynamics behind the main performance measures.

After running each case for 15 times, besides the average values of the performance measures, we also present the percent relative errors under 95% confidence interval calculated by the formula,

$$\% \text{ relative error} = \frac{t_{n-1, \frac{\alpha}{2}} \frac{s}{\sqrt{n}}}{\bar{x}}$$

Where, $n = 15$, $\alpha = 0.05$, $\bar{x}$ being the average value of the performance measures obtained after 15 runs and s being the standard deviation calculated by the formulas,

$$\bar{x} = \left(\frac{\sum_{i=1}^n x_i}{n} \right)$$

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{(n-1)}}$$

With the intention of keeping the results simpler and easier to understand, the percent errors and standard deviations are presented in the Appendix-B along with

the values of outputs. It can be seen that all of the percent relative errors are below 10% in order to reach this level of errors we have increased the replication numbers of some cases. Higher percent relative errors are anticipated while examining the profits in some cases because of the nature of the cases themselves, given that when a cost is increased greatly it results in higher variance in the outputs and since the revenue stays the same profits decrease and as a result of increased variance and lower profits, percent errors are expected to be higher.

It should also be noted that we have two types of service levels, the service levels are calculated by the formula,

$$\% \text{ service level} = \frac{\text{number of satisfied customers}}{\text{total demand}}$$

Although the same formula is used in both types of service level calculations, in the first one we assume that in cases of customers asking for substitute products, customer is regarded as an unsatisfied customer for the product that he could not buy due to stock out and depending on whether he is satisfied or unsatisfied with the second product he asked for, he is regarded as a satisfied or an unsatisfied customer for the second product that he asked for as well.

However while calculating the second type of service level that we define, we are only interested in the first product a customer asked for, and the customer is either considered as a satisfied or an unsatisfied for that product type, any actions after the first attempt of the customer to buy a product is ignored completely.

The reasoning behind having two types of service levels is that in the first type of service levels, service levels are always very close to each other, since the

unsatisfied customers that buy the other products if available. This causes the satisfaction rates to get distributed among three products. The second type of service levels allows us to see the actual service levels for each product type. It should also be mentioned that these service level types are not in any means comparable with each other, they are two different definitions for the service level and each service level type is evaluated and analyzed within its own results.

The results for all scenarios are presented in Tables from 4 to 9, it should be noted that the results of the base cases are repeated in both tables for each scenario since most of the comparisons include the base scenarios.

Table 4 – Results of Scenario 1

Scenario 1	Case 0		Case 1		Case 2		Case 3		Case 4		Case 5	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	53,853	85,083	46,017	87,520	20,079	45,861	68,760	90,840	49,257	83,788	60,207	85,129
Average Distributor Profit	28,808	27,753	22,439	21,981	33,489	32,289	33,050	25,650	26,457	25,758	25,083	27,485
Total Supply Chain Profit	140,277	168,344	113,333	153,462	121,188	143,149	167,910	167,790	128,629	161,064	135,457	167,586
Service Level (type 1) for Product 1	84.7%	85.6%	86.0%	86.1%	86.9%	88.2%	100.0%	100.0%	82.5%	83.2%	76.8%	85.1%
Service Level (type 1) for Product 2	84.7%	85.6%	87.1%	86.4%	85.8%	86.4%	100.0%	100.0%	82.2%	83.6%	78.1%	86.5%
Service Level (type 1) for Product 3	84.2%	85.3%	86.4%	86.2%	86.8%	88.2%	100.0%	100.0%	81.2%	81.7%	77.6%	85.8%
Service Level (type 2) for Product 1	87.0%	88.0%	87.7%	88.6%	88.5%	89.3%	100.0%	100.0%	84.8%	85.5%	85.3%	88.6%
Service Level (type 2) for Product 2	87.9%	89.4%	88.3%	89.0%	88.6%	89.1%	100.0%	100.0%	84.8%	85.2%	85.4%	88.5%
Service Level (type 2) for Product 3	85.6%	87.0%	87.9%	88.8%	88.4%	89.2%	100.0%	100.0%	84.5%	85.4%	85.1%	88.3%

Table 5 – Results of Scenario 1 Continued

Scenario 1	Case 0		Case 6		Case 7		Case 8		Case 9		Case 10	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	53,853	85,083	56,454	85,921	47,119	90,069	43,840	89,694	45,728	101,426	53,655	73,739
Average Distributor Profit	28,808	27,753	26,340	27,661	32,285	18,663	30,954	25,838	31,735	23,201	28,392	26,776
Total Supply Chain Profit	140,277	168,344	135,474	168,905	143,974	146,912	136,702	167,207	140,934	171,028	138,830	154,065
Service Level (type 1) for Product 1	84.7%	85.6%	80.8%	87.2%	96.0%	98.0%	84.3%	94.6%	93.9%	97.7%	77.8%	70.8%
Service Level (type 1) for Product 2	84.7%	85.6%	81.6%	87.5%	94.8%	97.6%	83.8%	94.9%	93.8%	97.3%	76.9%	70.8%
Service Level (type 1) for Product 3	84.2%	85.3%	80.3%	87.3%	93.8%	99.0%	88.1%	93.9%	93.8%	97.7%	76.2%	69.9%
Service Level (type 2) for Product 1	87.0%	88.0%	88.5%	90.4%	88.4%	91.2%	89.7%	91.9%	89.3%	92.2%	88.4%	90.4%
Service Level (type 2) for Product 2	87.9%	89.4%	88.7%	90.5%	88.1%	91.5%	89.7%	91.7%	89.3%	92.1%	88.4%	90.3%
Service Level (type 2) for Product 3	85.6%	87.0%	88.3%	90.2%	87.9%	91.4%	88.9%	92.2%	89.4%	92.1%	88.6%	90.5%

Table 6 – Results of Scenario 2

Scenario 2	Case 0		Case 1		Case 2		Case 3		Case 4		Case 5	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	98,171	121,360	98,272	126,992	39,085	23,470	76,935	136,260	89,268	119,181	96,492	122,104
Average Distributor Profit	44,904	46,196	37,483	41,072	51,410	49,781	51,475	43,060	41,231	44,856	39,508	46,260
Total Supply Chain Profit	232,882	259,946	210,721	250,208	193,315	172,814	269,375	265,440	212,960	253,751	215,015	260,884
Service Level (type 1) for Product 1	76.8%	74.9%	77.5%	75.4%	77.2%	73.1%	100.0%	100.0%	70.7%	72.0%	67.0%	74.7%
Service Level (type 1) for Product 2	78.2%	76.1%	78.4%	75.9%	79.0%	73.5%	100.0%	100.0%	69.7%	69.1%	71.0%	76.2%
Service Level (type 1) for Product 3	75.8%	73.4%	79.1%	77.1%	79.4%	73.3%	100.0%	100.0%	72.4%	72.7%	71.3%	76.0%
Service Level (type 2) for Product 1	84.3%	83.1%	83.6%	82.5%	84.0%	82.6%	100.0%	100.0%	81.6%	81.7%	82.4%	82.9%
Service Level (type 2) for Product 2	84.7%	82.9%	83.6%	82.0%	82.9%	81.2%	100.0%	100.0%	81.3%	80.3%	82.2%	81.6%
Service Level (type 2) for Product 3	82.5%	80.1%	81.4%	79.5%	82.3%	79.9%	100.0%	100.0%	80.3%	78.8%	81.3%	80.3%

Table 7 – Results of Scenario 2 Continued

Scenario 2	Case 0		Case 6		Case 7		Case 8		Case 9		Case 10	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	98,171	121,360	95,523	128,935	92,410	135,178	95,075	120,554	93,270	135,042	96,814	118,016
Average Distributor Profit	44,904	46,196	39,197	46,350	50,555	39,480	46,486	46,641	50,334	43,344	42,287	45,545
Total Supply Chain Profit	232,882	259,946	213,113	267,985	244,075	253,618	234,532	260,477	244,273	265,074	223,676	254,650
Service Level (type 1) for Product 1	76.8%	74.9%	69.6%	84.2%	91.0%	95.8%	72.2%	89.1%	90.2%	96.8%	70.2%	73.3%
Service Level (type 1) for Product 2	78.2%	76.1%	71.9%	84.5%	89.9%	94.9%	73.8%	87.6%	89.4%	95.5%	71.9%	74.2%
Service Level (type 1) for Product 3	75.8%	73.4%	70.6%	85.3%	92.5%	95.9%	72.1%	85.7%	88.9%	94.8%	71.7%	73.7%
Service Level (type 2) for Product 1	84.3%	83.1%	84.6%	85.0%	84.6%	85.6%	84.7%	86.2%	84.8%	86.9%	84.9%	86.3%
Service Level (type 2) for Product 2	84.7%	82.9%	84.5%	83.6%	84.5%	84.3%	84.5%	84.9%	84.5%	85.5%	84.7%	84.9%
Service Level (type 2) for Product 3	82.5%	80.1%	83.5%	82.5%	83.5%	83.2%	83.5%	83.8%	83.6%	84.4%	83.6%	83.7%

Table 8 – Results of Scenario 3

Scenario 3	Case 0		Case 1		Case 2		Case 3		Case 4		Case 5	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	80,923	130,292	56,993	135,710	93,512	118,205	124,950	136,117	67,956	133,367	85,340	132,897
Average Distributor Profit	50,816	42,863	43,539	31,383	54,944	52,934	51,475	48,512	48,994	35,764	48,194	43,639
Total Supply Chain Profit	233,370	265,477	187,609	229,859	258,343	277,008	279,375	281,654	214,938	240,659	229,921	263,813
Service Level (type 1) for Product 1	76.5%	76.2%	75.7%	76.6%	76.6%	75.9%	100.0%	100.0%	66.9%	67.2%	75.1%	75.5%
Service Level (type 1) for Product 2	76.6%	76.1%	75.7%	75.3%	76.8%	76.5%	100.0%	100.0%	67.5%	68.3%	75.0%	75.7%
Service Level (type 1) for Product 3	78.3%	75.2%	75.4%	76.2%	75.4%	76.3%	100.0%	100.0%	66.9%	68.5%	74.9%	76.0%
Service Level (type 2) for Product 1	77.1%	75.6%	78.1%	76.2%	77.2%	76.3%	100.0%	100.0%	71.7%	72.1%	76.9%	76.5%
Service Level (type 2) for Product 2	76.3%	76.8%	76.1%	75.9%	76.7%	76.4%	100.0%	100.0%	72.3%	71.7%	76.8%	76.7%
Service Level (type 2) for Product 3	77.5%	76.6%	77.5%	75.8%	76.8%	76.1%	100.0%	100.0%	71.7%	72.1%	76.8%	76.5%

Table 9 – Results of Scenario 3 Continued

Scenario 3	Case 0		Case 6		Case 7		Case 8		Case 9		Case 10	
	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI	RMI	VMI
Retailer Profit	79,867	132,799	88,344	135,000	61,282	128,941	75,729	135,525	84,157	148,439	76,671	128,754
Average Distributor Profit	50,693	43,448	47,640	40,701	53,571	33,735	50,384	40,573	51,178	39,700	49,793	43,352
Total Supply Chain Profit	231,946	263,144	231,264	257,104	221,994	230,145	226,881	257,244	237,690	267,540	226,049	258,811
Service Level (type 1) for Product 1	76.9%	75.6%	74.7%	73.9%	79.3%	79.7%	72.7%	77.2%	77.7%	78.3%	73.9%	72.8%
Service Level (type 1) for Product 2	76.4%	76.5%	75.1%	74.2%	78.5%	79.0%	73.0%	76.1%	76.8%	78.5%	74.5%	73.5%
Service Level (type 1) for Product 3	77.6%	75.4%	74.4%	75.1%	78.4%	78.4%	73.2%	77.1%	78.9%	77.0%	74.3%	74.1%
Service Level (type 2) for Product 1	77.8%	76.1%	76.4%	76.6%	76.6%	76.3%	76.8%	76.4%	76.9%	77.5%	76.9%	76.8%
Service Level (type 2) for Product 2	76.9%	76.3%	76.5%	76.6%	77.0%	76.1%	76.8%	76.2%	76.8%	77.1%	76.7%	76.9%
Service Level (type 2) for Product 3	77.7%	75.7%	76.8%	77.1%	76.3%	75.8%	77.4%	76.4%	76.3%	77.2%	76.6%	76.6%

The interpretation of the results are categorized under five headings: general results, the effect of the holding cost and the stock out cost, the effect of the demand variability, the effect of ordering frequency and the effect of the lead times.

General Results

As a consequence of the VMI model that is proposed in this study, retailer profits increase in VMI model compared to the RMI model, and average distributor profits tend to decrease, this is because in the VMI model the holding costs and the ordering costs of the retailer belong to the distributors.

Without doubt, this is just a certain type of VMI model, the agreement between the retailer and the distributor shapes the nature of the VMI model and various VMI models can be established. According to the VMI model in question, the results may be vastly different than the results of this VMI model.

Service levels in RMI models are generally higher than the ones in VMI models with some exceptions. The details of these exceptions are given in the

relevant topics. The general tendency of RMI having higher service levels is a result of higher stocks in the RMI model in comparison with the VMI model.

In addition, when total profit of the supply chain is examined in different cases, in most cases VMI is a better fit for a supply chain like the one proposed in this study. The main reason behind this outcome is that total holding costs of the supply chain is reduced, which leads to higher profits overall. There is only one case in which RMI is more profitable and a few other cases that RMI handles better, these cases is explained under the related headings.

The Effect of the Holding Cost and the Stock out Cost

The effect of the holding cost and the stock out cost are tested in the cases 1 and 2, and compared with the base case. It should be pointed out that the revenues are the same in all three cases of each scenario so although the profits are examined and analyzed, they are the exact indicator of the changing costs.

Retailer profits for both RMI and VMI models of scenario 2 are plotted in the Figure 4.

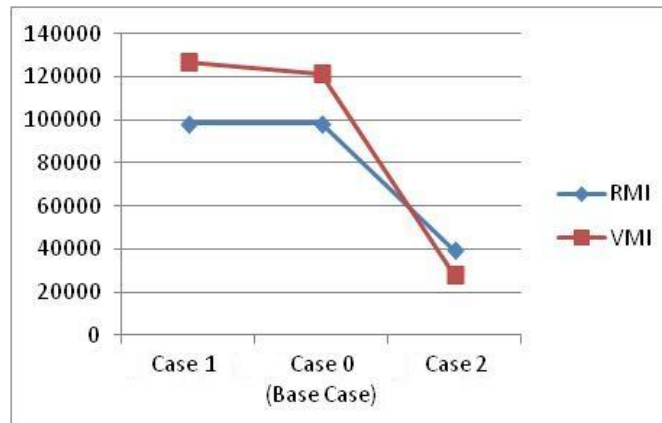


Figure 4 – Retailer profits in cases 0, 1 and 2 of scenario 2

Figure 4 shows a very specific case in which the RMI profit for the retailer is higher than the profits in VMI model. As the holding cost is decreased and the stock out cost is increased greatly as in case 2, RMI model becomes more profitable for the retailer than the VMI model. This can be explained by looking at the service levels in both models, it can be seen from the results that in general RMI cases have higher service levels than VMI cases, which suggests that in VMI cases stock outs occur more often, therefore VMI model is further affected by the changes in the stock out cost.

This result is reflected to the total supply chain profit as well making the whole supply chain more profitable by using the RMI model in the case 2 of scenario 2. It should also be mentioned that in same case types of different scenarios 1 and 3 the results are similar, although RMI model is never more profitable in those cases; it can handle the stock out cost increase better compared to the VMI model.

When case type 1 is compared with the base case, it is evident that VMI becomes a better fit for the supply chain, this is because in case type 1 the holding cost is increased while the stock out cost is decreased, and since the main cost type the RMI suffers is the holding cost because of the excessive inventory holding

required by the model itself, VMI is superior compared to the RMI considering the case in which holding costs are higher and the stock out cost is lower. Total supply chain profits for the same cases are presented in Figure 5.

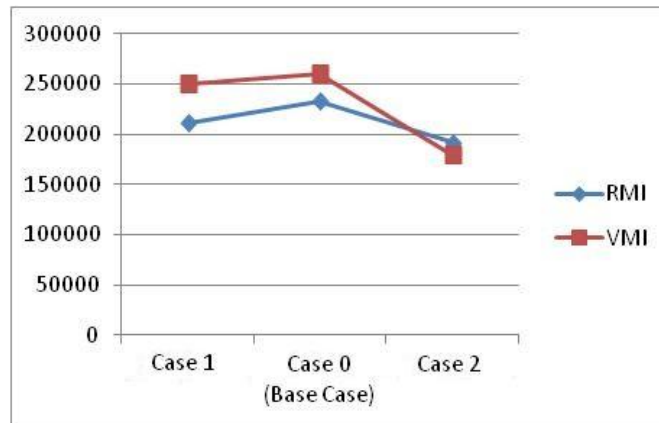


Figure 5 – Total supply chain profits in cases 0, 1 and 2 of scenario 2

As for the distributors, average distributor profits are plotted in Figure 6. Average distributor profits for RMI are lower in the case type 1 as the holding costs are higher in that case and distributors mainly experience higher holding costs in the RMI case, however as the holding costs become lower and almost insignificant, the average profit of distributors in the RMI and the VMI models are almost the same, showing us that distributors are not greatly affected by the high stock out costs, but holding costs are a major type of cost for the distributors especially in the RMI model.

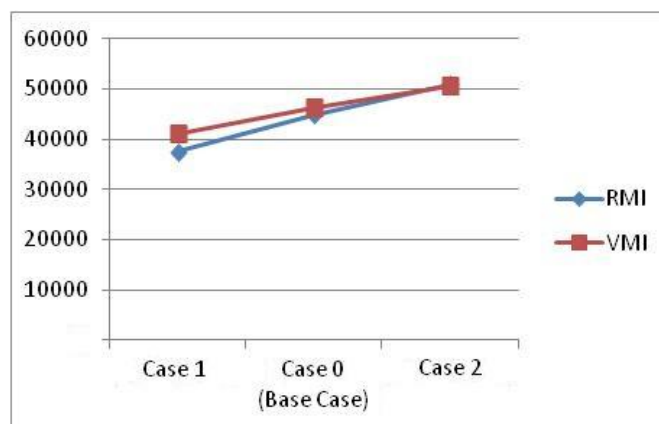


Figure 6 – Average distributor profits in cases 0, 1 and 2 of scenario 2

It should be emphasized that same case types run in other scenarios reflect the same results as well but the scenario 2 is used as an illustrative example since it involves the most distinctive results.

The Effect of Demand Variability

Cases 3 and 4 are the cases in which the demand variability is tested, in the case 3 the standard deviation is zero for all demands and in the case 4 standard deviations are doubled creating a considerable variability in the end demand of the products.

As expected, when case 3 is in question for all three scenarios, the service levels become 100% since when the variability is taken to zero there is no space for mistakes in the replenishment processes, while this does not directly reflect to the profits of the supply chain.

Although the revenues are increased, the costs increase as well especially because of the unnecessary holding costs. When there is no variability in the demand at all, normally the members of the supply chain should be able to meet the end demand with very low stocks; however in our model since there are starting inventories which are not utilized during the simulation causes the profits to be lower than expected.

The most remarkable result that we obtain in the case of zero demand variability is that in all three scenarios, the total supply chain profits of RMI and the VMI models are closer to each other than any other case as shown in Figure 7. In the

bases cases of all scenarios VMI model generates a higher profit than RMI model supply chain wise, so this result shows us that RMI model and VMI model has almost no difference supply chain wise in the absence of demand variability.

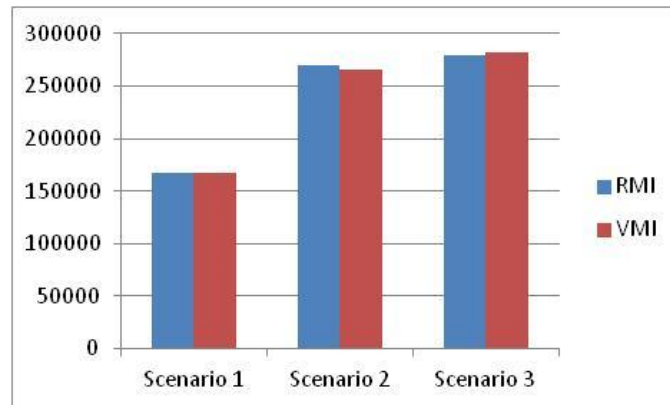


Figure 7 – Total supply chain profits for both models in all scenarios in case 3

In the first two scenarios where the replenishment model used is the moving average of the last thirty time steps, in the VMI model the average distributor profits are lower compared to the base cases as shown in Figure 8, the reason behind this counter intuitive situation is that the unnecessary inventory holding causes the distributors profit to decrease since all the holding costs belong to the distributors in the case of VMI.

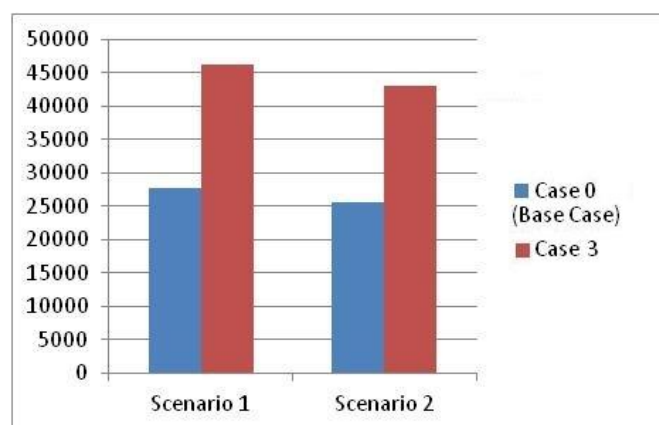


Figure 8 – Average distributor profits of VMI models for scenarios 1 and 2 for comparison of cases 0 and 3

In the third scenario, in which the fixed ordering policy is utilized, the average distributor profit increases unlike in the first two scenarios as shown in Figure 9. The reasoning behind this is that since fixed ordering policy does not work very well under the presence of demand variability, the holding costs of distributors in the base case are higher compared to the zero demand variation case.

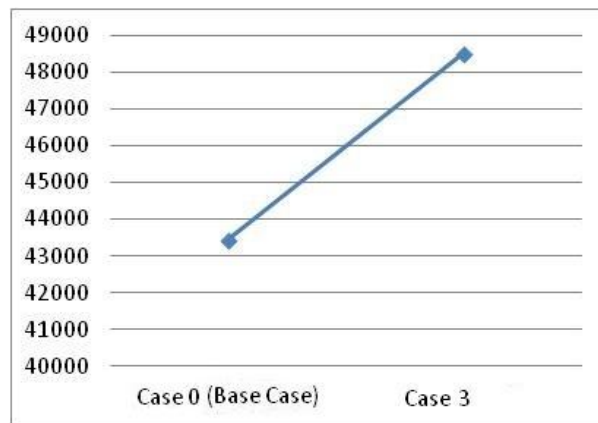


Figure 9 – Average distributor profit of VMI model of scenario 3

In the case 4 when demand variability is doubled, the total supply chain profit for both the RMI and the VMI models decrease as expected as shown in Figure 10. The service levels of the supply chain decrease as well, especially in the third scenario as presented in Figure 11.

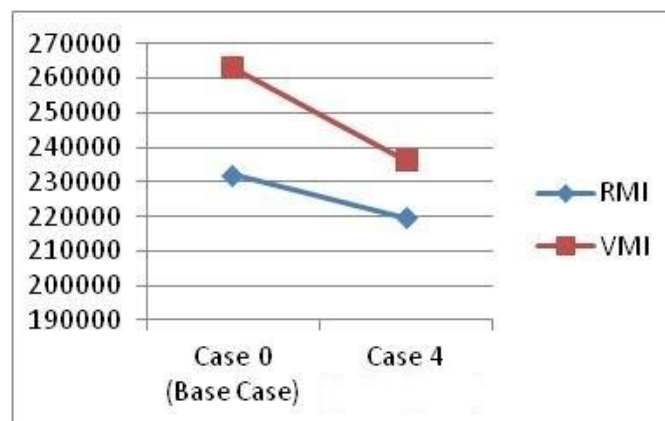


Figure 10 – Total supply chain profit of scenario 3 for comparison of cases 0 and 4

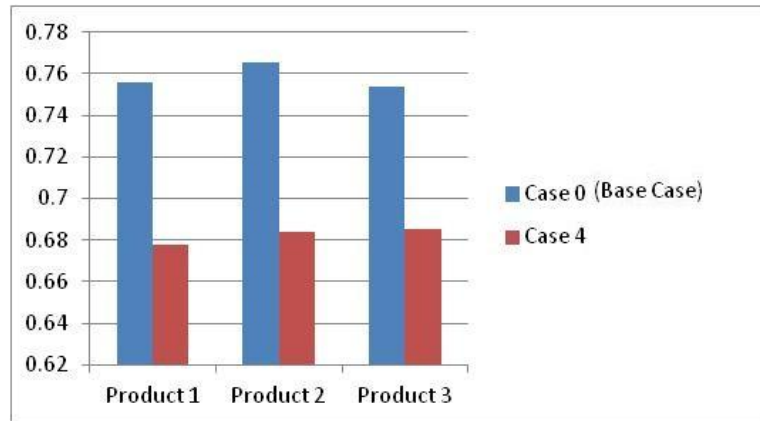


Figure 11- Service levels (Type 1) of Scenario 3 for comparison of cases 0 and 4

Even though the type 1 service level of scenario 3 is the only result illustrated in the figure, the results for other scenarios and the other service level type are also consistent with this structure.

In the scenario 1 and 2, the decrease in the profit of the supply chain of the VMI models are less than the decrease in the RMI models, advising that the VMI model can handle the increased variance better than the RMI model when moving average replenishment policy is in effect. On the other hand in the third scenario, where fixed amounts are ordered every time, the VMI model suffers from a greater loss profit wise compared to the RMI model. This suggests that while deciding on the model, the replenishment policy is a key decision.

The Effect of Ordering Frequency

Case 5 is related to the ordering frequency of the retailer and in cases 6 and 7 ordering frequency of the distributors are changed for trial.

When the results of the case 5 are examined in which the retailer orders less frequently, total profit of the supply chain is lower in the RMI models when the ordering frequency of the retailer is increased as shown in Figure 12, for the VMI models the profit remains the same as illustrated in the Figure 13 since the retailer does not give any orders in the VMI model.

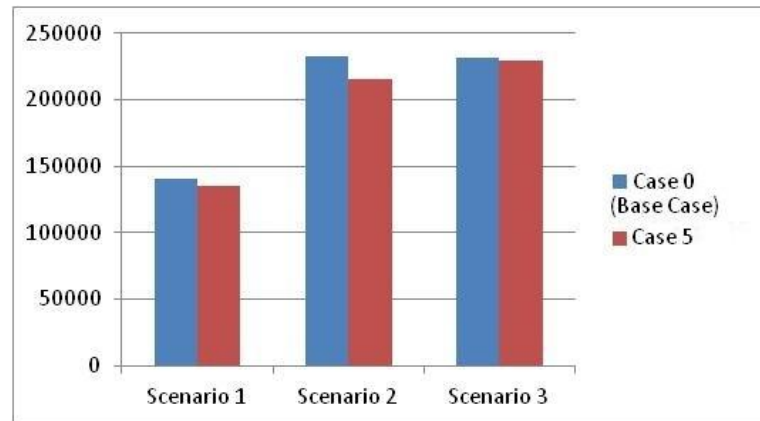


Figure 12 – Total supply chain of profit in RMI models for all scenarios for comparison of cases 0 and 5

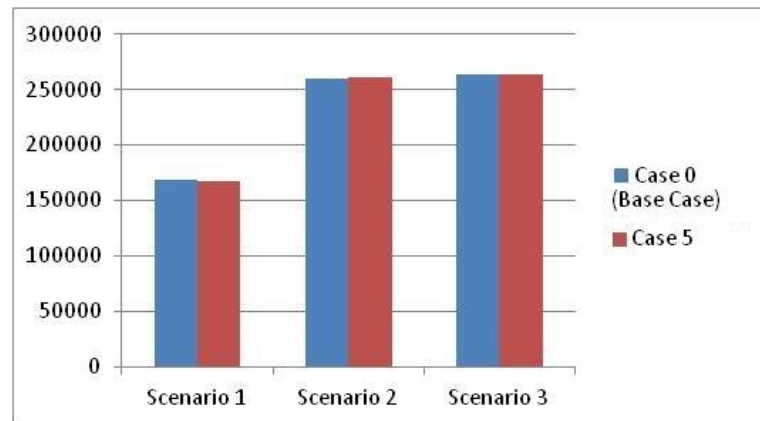


Figure 13 – Total supply chain of profit in VMI models for all scenarios for comparison of cases 0 and 5

The decrease in the total supply chain profits while comparing the base case and the case 5 can be easily explained by the lower service levels while comparing two cases as shown in Figure 14.

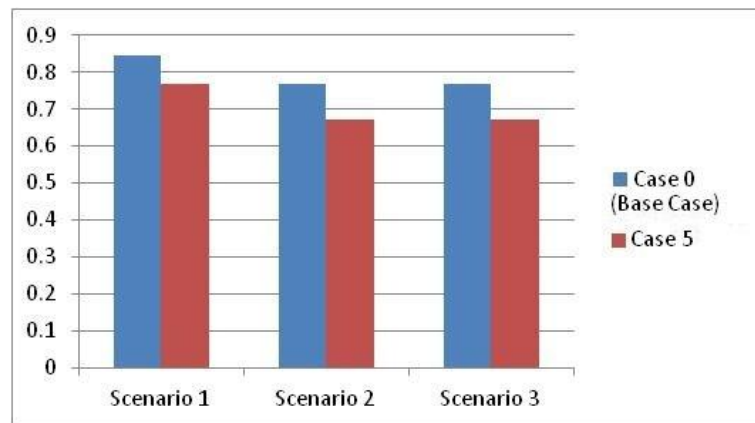


Figure 14 – Type 1 service levels of product 1 in RMI models for all scenarios for comparison of cases 0 and 5

The service levels for only one product are introduced in the figure as the other results are also consistent with this one. It is not possible to observe the same ratio of change in the type 2 service levels, this is due to the fact that in service level type 1 the effects of the brand competition is included as mentioned before, a customer can be an unsatisfied customer for more than one time in the first type of service level.

When type 2 service levels are examined, there are slight decreases when case 5 is compared to the base cases for all scenarios.

When ordering frequency of all products is increased, the stock outs occur more often causing the customers to try to satisfy their demands by substitute products, thus retailer runs out of all three product types even faster than it would normally do resulting in lower service levels for each product type.

As a consequence every manufacturer has a hard time meeting up with their own demand once the retailer runs out of a certain product. Given that the only input the manufacturers have is the order amounts from the retailer in the RMI model.

As the ordering frequency of the manufacturers are increased (case 6), so that they give orders less frequently in the RMI model the supply chain profits drop, however in the VMI model the profits almost stays the same, in the scenario with the fixed orders, profits stay almost the same in both RMI and VMI models (see Figures 15 and 16).

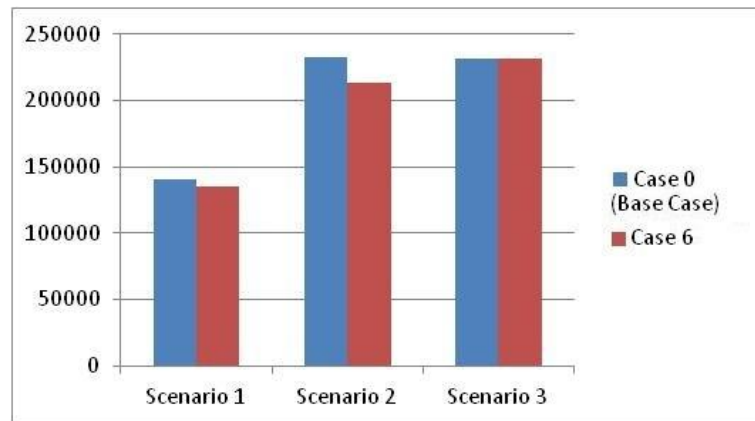


Figure 15 – Total supply chain profit of the RMI model for comparison of cases 0 and 6

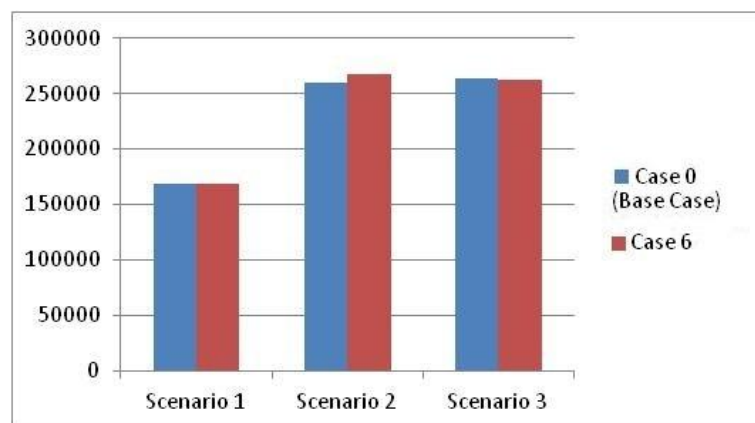


Figure 16 – Total supply chain profit of the VMI model for comparison of cases 0 and 6

The decreased RMI profits in the first and second scenario are an expected result with the same reasoning mentioned in the case of increased retailer ordering frequency; however in the third scenario profits stay the same, the cause for this

result is most likely that higher order amounts work better with the fixed ordering since it fails to capture the changes in the demand, larger order lots can make up for the loss that is caused by the increased order frequency in the scenario with fixed ordering.

When VMI results are examined, since VMI can handle the increased order frequency better due to its more flexible nature, as seen in all the scenarios, the profits are either the same or very slightly increased. Since there is fixed ordering cost no matter what the order size is, distributors profits increase because of ordering less frequently.

In the case 7, where the manufacturer order more frequently in smaller lots, the service levels are increased for all scenarios (see Figure 17).

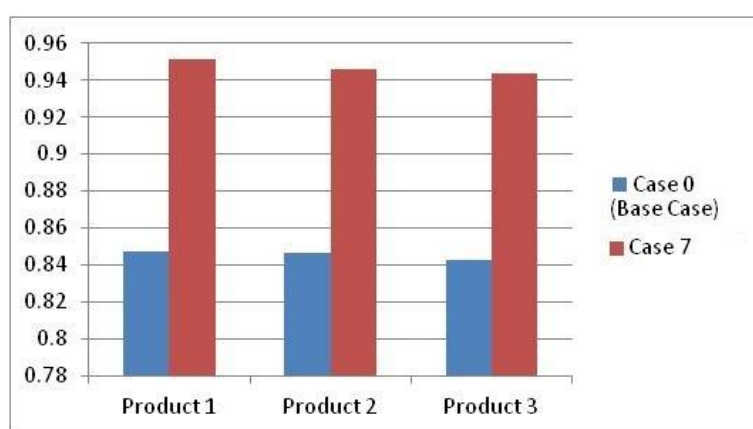


Figure 17 – Type 1 service levels of the RMI model of Scenario 1 for comparison of cases 0 and 7

While only type 1 service level of the RMI model of the scenario 1 is presented in the figure, all of the other results are consistent with this one, in all of the scenarios and all of the models service levels increase when the ordering frequency of the

manufacturers are lower which means that they order more frequently, which is an expected outcome.

When the total supply chain profits are examined, because of the fixed ordering cost mentioned above the profits tend to decrease especially in the VMI model as shown in Figure 18. Although an increase in profit is expected as lot sizes get smaller and orders are more frequent, fixed ordering cost in our model caused the results to be opposite of what is typically expected.

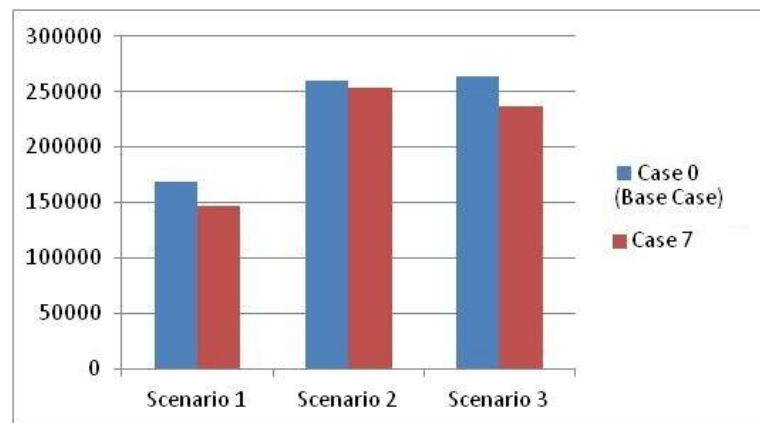


Figure 18 – Total supply chain profit in the VMI model of all scenarios for comparison of base case and case type 7

The Effect of Lead Times

The effects of the lead times are not very significant in our model since we did not use stochastic lead times in our model, and with fixed lead times the only results are the ones that are expected. Higher lead times whether it is between the retailer and the distributor or the distributor and the manufacturer generally resulted in small

decreases in the total supply chain profit, and lower lead times between the distributor and the manufacturer increased the profits slightly.

Figure 19 shows the total supply chain profits of VMI models in all scenarios, for increased lead times (cases 8 and 10). Results of the RMI model are also coherent with results of the VMI results.

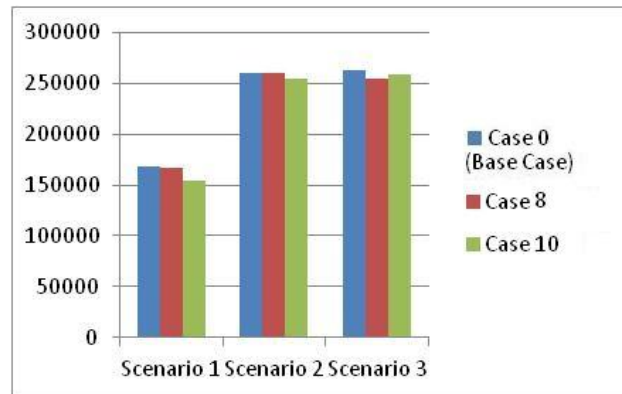


Figure 19 – Total supply chain profits in the VMI model of all scenarios for comparison of cases 0, 8 and 10

In Figure 20, base case is compared with the case 9 in which lead times are lower compared to the base case and minor increases in the results of the RMI model is presented in the figure this time; however the results of the VMI model are consistent with the illustrated results of the RMI model as well.

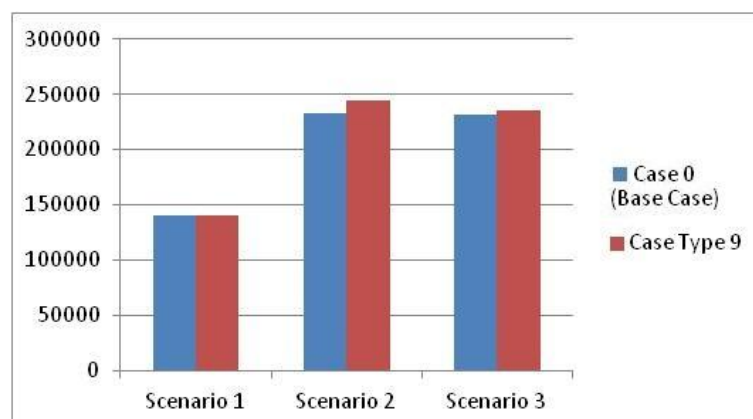


Figure 20 - Total supply chain profits in the RMI model of all scenarios for comparison of cases 0 and 9

CHAPTER 7: CONCLUSION

In this study we simulated a supply chain model in which competition exists among three different brands using agent based modeling and we assessed the suitability of RMI and VMI models in such a supply chain with the help of this simulation model. We also aimed to find the effects of different input parameters on the performance measures of the simulation.

After examining and analyzing the outputs of our settings in sensitivity analysis, we found out that VMI model that we have proposed is in general a better fit for a supply chain of this kind, but it should be mentioned that the implementation part of the VMI model is also very significant element and we assumed to have an intact VMI relationship between the members of the supply chain. We also discovered that RMI model becomes more appropriate for our supply chain model, in the case of increased stock out costs.

We concluded that a supply chain that is using VMI model has less troubles dealing with the variations in demand and high holding costs. Another result that we found out is that the ordering frequency is a major decision in both RMI and VMI models in the existence of fixed ordering costs like in our supply chain. We determined that variations in the lead times provided that lead times are stochastic like in our model, they have little to no effect in the performance measures.

Our model is limited by having three manufacturers, three distributors and one retailer; also we used only one type of demand distribution. The replenishment methods utilized in our model relies on the orders and the demands.

As further studies, a generic model to compare the RMI and VMI systems can be developed. The addition of multiple demand distributions to the model can make the model more useful and lastly continuous review models for replenishment processes which take the current inventories into account can reveal other essential results.

APPENDIX A

Input Parameters

General Parameters for Base Case of Scenario 1

Demand of the first product (units)	40
Demand of the second product (units)	40
Demand of the third product (units)	40
Standard deviation of the demand of the first product (units)	10
Standard deviation of the demand of the second product (units)	10
Standard deviation of the demand of the third product (units)	10
End of simulation (time steps)	250
Replication number	15

Parameters Related to Customers for Base Case of Scenario 1

Number of customer segments	3
Customer waiting time (time steps)	2
Probability of customer being from the first segment	33%
Probability of customer being from the second segment	33%
Probability of customer being from the third segment	34%

Customer Decision Matrix Values of First Customer Segment for Base Case of Scenario 1

Probability of waiting for the product	70%
Probability of asking for another product	20%
Probability of quitting without buying any product	10%

Customer Decision Matrix Values of Second Customer Segment for Base Case of Scenario 1

Probability of waiting for the product	70%
Probability of asking for another product	20%
Probability of quitting without buying any product	10%

Customer Decision Matrix Values of Third Customer Segment for Base Case of Scenario 1

Probability of waiting for the product	25%
Probability of asking for another product	50%
Probability of quitting without buying any product	25%

Parameters Related to the Retailer for Base Case of Scenario 1

Sales price of product 1 (per unit)	10
Sales price of product 2 (per unit)	10
Sales price of product 3 (per unit)	10
Ordering cost (per order)	30
Holding cost (per unit per time step)	0.5
Stock out cost of customer quitting (per each quitting customer)	0.5
Stock out cost of customer waiting (per each waiting customer)	0.5
Stock out cost of customer replacing (for each replacing customer)	0.5
Starting inventory of product 1 (units)	200
Starting inventory of product 2 (units)	200
Starting inventory of product 3 (units)	200
Ordering frequency of product 1 (time steps)	1
Ordering frequency of product 2 (time steps)	1
Ordering frequency of product 3 (time steps)	1

Parameters Related to the Distributor 1 for Base Case of Scenario 1

Sales price (per unit)	7
Ordering cost (per order)	20
Holding cost (per unit per time step)	0.5
Stock out cost (per unit)	0.5
Starting Inventory (units)	100
Ordering frequency (time steps)	3
Lead time (time steps)	1

Parameters Related to the Distributor 2 for Base Case of Scenario 1

Sales price (per unit)	7
Ordering cost (per order)	20
Holding cost (per unit per time step)	0.5
Stock out cost (per unit)	0.5
Starting Inventory (units)	100
Ordering frequency (time steps)	3
Lead time (time steps)	1

Parameters Related to the Distributor 3 for Base Case of Scenario 1

Sales price (per unit)	7
Ordering cost (per order)	20
Holding cost (per unit per time step)	0.5
Stock out cost (per unit)	0.5
Starting Inventory (units)	100
Ordering frequency (time steps)	3
Lead time (time steps)	1

Parameters Related to the Manufacturer 1 for Base Case of Scenario 1

Sales price (per unit)	3
Starting inventory (units)	100000
Lead time (time steps)	2

Parameters Related to the Manufacturer 1 for Base Case of Scenario 1

Sales price (per unit)	3
Starting inventory (units)	100000
Lead time (time steps)	2

Parameters Related to the Manufacturer 1 for Base Case of Scenario 1

Sales price (per unit)	3
Starting inventory (units)	100000
Lead time (time steps)	2

Input Parameters Which Are Different in Base Cases of Scenario 2 and 3

Demand of product 1 (units)	40
Demand of product 2 (units)	50
Demand of product 3 (units)	60
Standard deviation of the demand of product 1 (units)	10
Standard deviation of the demand of product 2 (units)	12.5
Standard deviation of the demand of product 3(units)	15
Sales price of product 1 in retailer (per unit)	15
Sales price of product 2 in retailer (per unit)	12
Sales price of product 3 in retailer (per unit)	10
Sales price of product 1 in distributor (per unit)	10.5
Sales price of product 2 in distributor (per unit)	8.4
Sales price of product 3 in distributor (per unit)	7
Sales price of product 1 in manufacturer(per unit)	4.5
Sales price of product 2 in manufacturer (per unit)	3.6
Sales price of product 3 in manufacturer (per unit)	3

Adjusted Input Parameters in All Case Types

Case 1	Holding cost for retailer and distributors= 1, Stock out cost for retailer and distributors = 0.1
Case 2	Holding cost for retailer and distributors = 0.1, Stock out cost for retailer and distributors = 10
Case 3	Standard deviation of all demands = 0
Case 4	Standard deviation of all demands are doubled
Case 5	Order frequency of retailer for all products = 2
Case 6	Order frequency of all distributors = 4
Case 7	Order frequency of all distributors = 1
Case 8	Lead time of all distributors = 3
Case 9	Lead time of all manufacturers = 1
Case 10	Lead time of all manufacturers = 4

APPENDIX B

Results of Experiments

Case #1

Scenario 1	Base Case					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	284318.00	5284.43	1.03%	285496.00	5132.73	1.00%
Retailer Cost	230465.17	6184.47	1.49%	200412.73	2910.45	0.80%
Retailer Profit	53852.83	1801.54	1.85%	85083.27	2296.69	1.49%
Distributor 1 Revenue	65302.07	2086.83	1.77%	65975.00	2213.51	1.86%
Distributor 1 Cost	36446.73	1455.40	2.21%	38273.53	2293.07	3.32%
Distributor 1 Profit	28855.33	1344.23	2.58%	27701.47	765.41	1.53%
Distributor 2 Revenue	65634.33	3252.97	2.74%	66249.40	3322.66	2.78%
Distributor 2 Cost	36463.00	1789.26	2.72%	38385.03	3067.10	4.43%
Distributor 2 Profit	29171.33	2074.95	3.94%	27864.37	1150.23	2.29%
Distributor 3 Revenue	64649.67	2444.63	2.09%	65662.80	2006.90	1.69%
Distributor 3 Cost	36252.10	940.54	1.44%	37968.33	2209.72	3.22%
Distributor 3 Profit	28397.57	2011.85	3.92%	27694.47	827.13	1.65%
Service Level (type 1) for Product 1	84.70%	4.77%	3.12%	85.59%	5.17%	3.35%
Service Level (type 1) for Product 2	84.67%	5.68%	3.72%	85.65%	6.22%	4.02%
Service Level (type 1) for Product 3	84.23%	4.66%	3.06%	85.27%	5.00%	3.25%
Service Level (type 2) for Product 1	87.69%	2.06%	1.31%	88.63%	1.73%	1.09%
Service Level (type 2) for Product 2	88.32%	1.72%	1.08%	89.00%	1.47%	0.91%
Service Level (type 2) for Product 3	87.90%	1.90%	1.23%	88.85%	1.35%	0.86%
Total Revenue	479904.07	8999.62	1.04%	483383.20	8777.15	1.01%
Total Cost	339627.00	8236.04	1.34%	315039.63	7083.35	1.25%
Total Profit	140277.07	3615.97	1.43%	168343.57	2417.18	0.80%

Case #2

Scenario 1	Case Type 1					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	285927.33	3526.00	0.68%	286864.00	4524.26	0.87%
Retailer Cost	239909.89	8394.55	1.94%	199343.99	3096.48	0.86%
Retailer Profit	46017.44	7228.32	8.70%	87520.01	1431.55	0.91%
Distributor 1 Revenue	65162.07	2881.68	2.45%	65924.60	2471.23	2.08%
Distributor 1 Cost	43336.24	1788.74	2.29%	44216.40	4238.62	5.31%
Distributor 1 Profit	21825.83	3119.44	7.92%	21708.20	2506.52	6.39%
Distributor 2 Revenue	65827.07	2371.71	2.00%	66553.20	2428.43	2.02%
Distributor 2 Cost	42822.71	2273.78	2.94%	44327.40	3490.80	4.36%
Distributor 2 Profit	23004.36	1624.84	3.91%	22225.80	1953.41	4.87%
Distributor 3 Revenue	65727.20	2524.05	2.13%	66389.40	2466.73	2.06%
Distributor 3 Cost	43241.77	2532.52	3.24%	44381.67	3761.01	4.69%
Distributor 3 Profit	22485.43	3043.63	7.50%	22007.73	1857.43	4.67%
Service Level (type 1) for Product 1	86.02%	5.00%	3.22%	86.08%	5.36%	3.45%
Service Level (type 1) for Product 2	87.07%	3.77%	2.40%	86.43%	4.18%	2.68%
Service Level (type 1) for Product 3	86.41%	4.76%	3.05%	86.24%	4.85%	3.12%
Service Level (type 2) for Product 1	87.69%	0.33%	0.21%	88.63%	0.30%	0.19%
Service Level (type 2) for Product 2	88.32%	0.32%	0.20%	89.00%	0.22%	0.14%
Service Level (type 2) for Product 3	87.90%	0.23%	0.14%	88.85%	0.15%	0.09%
Total Revenue	482643.67	6004.32	0.69%	485731.20	7731.94	0.88%
Total Cost	369310.61	11185.47	1.68%	332269.45	8995.32	1.50%
Total Profit	113333.05	9865.70	4.82%	153461.75	4966.34	1.79%

Case #3

Scenario 1	Case Type 2					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	288947.66	2977.71	0.57%	289083.81	3172.29	0.55%
Retailer Cost	265398.16	3740.61	0.74%	241725.10	6336.30	1.37%
Retailer Profit	23549.50	3415.24	8.71%	47358.71	7903.02	9.14%
Distributor 1 Revenue	66056.59	1596.62	1.24%	66023.37	1519.75	1.21%
Distributor 1 Cost	31389.91	705.66	1.21%	33793.84	787.88	1.17%
Distributor 1 Profit	34666.68	861.33	1.25%	32229.52	768.93	1.27%
Distributor 2 Revenue	64711.38	1733.60	1.46%	65999.16	1453.89	1.15%
Distributor 2 Cost	31784.29	761.83	1.22%	33762.92	796.92	1.24%
Distributor 2 Profit	32927.09	1065.90	1.74%	32236.24	648.83	1.06%
Distributor 3 Revenue	65143.80	1868.26	1.50%	66443.64	1854.19	1.51%
Distributor 3 Cost	32270.37	793.68	1.24%	34041.69	991.38	1.44%
Distributor 3 Profit	32873.43	1170.80	1.85%	32401.95	929.72	1.53%
Service Level (type 1) for Product 1	87.33%	3.44%	2.04%	88.26%	3.21%	1.87%
Service Level (type 1) for Product 2	85.20%	3.32%	2.01%	86.39%	3.65%	2.26%
Service Level (type 1) for Product 3	87.26%	3.84%	2.22%	87.41%	4.04%	2.44%
Service Level (type 2) for Product 1	88.91%	0.17%	0.10%	88.67%	0.18%	0.10%
Service Level (type 2) for Product 2	89.34%	0.08%	0.05%	89.75%	0.11%	0.07%
Service Level (type 2) for Product 3	88.05%	0.11%	0.07%	88.62%	0.17%	0.10%
Total Revenue	484859.42	5180.47	0.57%	487549.98	5390.40	0.58%
Total Cost	360842.74	4274.81	0.60%	343323.55	5722.91	0.91%
Total Profit	124016.69	4076.42	1.75%	144226.43	8519.40	3.00%

Case #4

Scenario 1	Case Type 3					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	300000.00	0.00	0.00%	300000.00	0.00	0.00%
Retailer Cost	231240.00	0.00	0.00%	209160.00	0.00	0.00%
Retailer Profit	68760.00	0.00	0.00%	90840.00	0.00	0.00%
Distributor 1 Revenue	69580.00	0.00	0.00%	69720.00	0.00	0.00%
Distributor 1 Cost	36530.00	0.00	0.00%	44070.00	0.00	0.00%
Distributor 1 Profit	33050.00	0.00	0.00%	25650.00	0.00	0.00%
Distributor 2 Revenue	69580.00	0.00	0.00%	69720.00	0.00	0.00%
Distributor 2 Cost	36530.00	0.00	0.00%	44070.00	0.00	0.00%
Distributor 2 Profit	33050.00	0.00	0.00%	25650.00	0.00	0.00%
Distributor 3 Revenue	69580.00	0.00	0.00%	69720.00	0.00	0.00%
Distributor 3 Cost	36530.00	0.00	0.00%	44070.00	0.00	0.00%
Distributor 3 Profit	33050.00	0.00	0.00%	25650.00	0.00	0.00%
Service Level (type 1) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Total Revenue	508740.00	0.00	0.00%	509160.00	0.00	0.00%
Total Cost	340830.00	0.00	0.00%	341370.00	0.00	0.00%
Total Profit	167910.00	0.00	0.00%	167790.00	0.00	0.00%

Case #5

Scenario 1	Case Type 4					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	282454.67	10479.95	2.05%	283513.33	8059.84	1.57%
Retailer Cost	233197.70	10153.25	2.41%	199725.03	4589.79	1.27%
Retailer Profit	49256.97	5290.11	5.95%	83788.30	3582.72	2.37%
Distributor 1 Revenue	65606.80	4155.66	3.51%	66434.20	3991.60	3.33%
Distributor 1 Cost	38473.00	2455.81	3.54%	39947.77	3847.83	5.33%
Distributor 1 Profit	27133.80	2697.16	5.51%	26486.43	1901.64	3.98%
Distributor 2 Revenue	64532.07	4214.40	3.62%	65912.00	4120.33	3.46%
Distributor 2 Cost	38504.13	4332.77	6.23%	40525.93	5591.33	7.64%
Distributor 2 Profit	26027.93	2682.98	5.71%	25386.07	2318.69	5.06%
Distributor 3 Revenue	64218.47	3732.97	3.22%	64306.20	3960.83	3.41%
Distributor 3 Cost	38008.17	3483.05	5.08%	38903.43	4489.55	6.39%
Distributor 3 Profit	26210.30	2481.48	5.24%	25402.77	2165.60	4.72%
Service Level (type 1) for Product 1	82.50%	5.84%	3.92%	83.23%	6.97%	4.64%
Service Level (type 1) for Product 2	82.19%	8.08%	5.45%	83.60%	9.06%	6.00%
Service Level (type 1) for Product 3	81.15%	7.73%	5.28%	81.72%	8.44%	5.72%
Service Level (type 2) for Product 1	84.75%	0.34%	0.22%	85.51%	0.40%	0.26%
Service Level (type 2) for Product 2	84.81%	0.38%	0.25%	85.25%	0.34%	0.22%
Service Level (type 2) for Product 3	84.48%	0.43%	0.28%	85.36%	0.51%	0.33%
Total Revenue	476812.00	17891.43	2.08%	480165.73	13902.66	1.60%
Total Cost	348183.00	16144.69	2.57%	319102.17	12972.83	2.25%
Total Profit	128629.00	9433.43	4.06%	161063.57	3359.60	1.16%

Case #6

Scenario 1	Case Type 5					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	274893.33	8020.03	1.62%	285482.67	6611.43	1.28%
Retailer Cost	214686.60	5794.19	1.49%	200353.30	3668.77	1.01%
Retailer Profit	60206.73	2427.15	2.23%	85129.37	3021.97	1.97%
Distributor 1 Revenue	62539.40	3249.65	2.88%	65465.40	2803.80	2.37%
Distributor 1 Cost	37686.23	1663.22	2.44%	37828.50	2399.58	3.51%
Distributor 1 Profit	24853.17	1989.50	4.43%	27636.90	1080.60	2.17%
Distributor 2 Revenue	63812.93	3584.35	3.11%	66180.80	2953.45	2.47%
Distributor 2 Cost	38433.50	1886.82	2.72%	39122.20	3299.58	4.67%
Distributor 2 Profit	25379.43	2439.85	5.32%	27058.60	1495.86	3.06%
Distributor 3 Revenue	63282.80	2498.61	2.19%	66229.80	2211.17	1.85%
Distributor 3 Cost	38265.10	1721.63	2.49%	38469.07	2268.78	3.27%
Distributor 3 Profit	25017.70	2240.46	4.96%	27760.73	781.81	1.56%
Service Level (type 1) for Product 1	76.84%	6.55%	4.72%	85.08%	6.68%	4.35%
Service Level (type 1) for Product 2	78.10%	7.07%	5.01%	86.52%	7.88%	5.04%
Service Level (type 1) for Product 3	77.65%	5.40%	3.85%	85.82%	5.93%	3.82%
Service Level (type 2) for Product 1	85.31%	0.42%	0.28%	88.57%	0.16%	0.10%
Service Level (type 2) for Product 2	85.40%	0.39%	0.26%	88.53%	0.13%	0.08%
Service Level (type 2) for Product 3	85.08%	0.34%	0.22%	88.32%	0.10%	0.06%
Total Revenue	464528.47	13692.66	1.63%	483358.67	11302.12	1.30%
Total Cost	329071.43	7907.39	1.33%	315773.07	9142.24	1.60%
Total Profit	135457.03	6515.19	2.66%	167585.60	3089.40	1.02%

Case #7

Scenario 1	Case Type 6					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	279866.67	4334.85	0.86%	287440.00	2689.52	0.52%
Retailer Cost	223412.63	3432.04	0.85%	201518.97	1780.47	0.49%
Retailer Profit	56454.03	1862.97	1.83%	85921.03	1009.93	0.65%
Distributor 1 Revenue	63976.73	1817.53	1.57%	66516.80	1647.58	1.37%
Distributor 1 Cost	37815.60	1321.81	1.94%	38767.00	1194.30	1.71%
Distributor 1 Profit	26161.13	1272.40	2.69%	27749.80	657.05	1.31%
Distributor 2 Revenue	64638.93	2477.13	2.12%	66421.60	1689.31	1.41%
Distributor 2 Cost	38118.77	1467.20	2.13%	38907.53	1564.68	2.23%
Distributor 2 Profit	26520.17	1420.66	2.97%	27514.07	845.68	1.70%
Distributor 3 Revenue	63819.93	1903.42	1.65%	66492.53	1327.42	1.11%
Distributor 3 Cost	37480.87	1236.85	1.83%	38772.77	1113.35	1.59%
Distributor 3 Profit	26339.07	1081.84	2.27%	27719.77	680.04	1.36%
Service Level (type 1) for Product 1	80.79%	3.96%	2.71%	87.20%	1.92%	1.22%
Service Level (type 1) for Product 2	81.62%	5.09%	3.46%	87.47%	3.02%	1.91%
Service Level (type 1) for Product 3	80.29%	4.03%	2.78%	87.25%	2.54%	1.61%
Service Level (type 2) for Product 1	88.47%	0.18%	0.11%	90.40%	0.02%	0.01%
Service Level (type 2) for Product 2	88.67%	0.17%	0.11%	90.46%	0.03%	0.02%
Service Level (type 2) for Product 3	88.28%	0.20%	0.12%	90.23%	0.03%	0.02%
Total Revenue	472302.27	7382.76	0.87%	486870.93	4575.33	0.52%
Total Cost	336827.87	4806.47	0.79%	317966.27	3322.06	0.58%
Total Profit	135474.40	3275.52	1.34%	168904.67	1615.72	0.53%

Case #8

Scenario 1	Case Type 7					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	298814.23	2446.84	0.41%	298299.65	2375.39	0.40%
Retailer Cost	251695.67	6261.87	1.27%	208230.81	1637.07	0.42%
Retailer Profit	47118.56	5833.24	7.31%	90068.84	753.41	0.42%
Distributor 1 Revenue	68907.92	1547.61	1.18%	69621.51	1332.76	0.99%
Distributor 1 Cost	36017.68	1223.14	1.75%	51060.74	2967.94	3.04%
Distributor 1 Profit	32890.24	1798.91	2.87%	18560.77	2941.73	8.51%
Distributor 2 Revenue	68251.23	1800.54	1.43%	69612.54	1314.78	0.97%
Distributor 2 Cost	36788.16	1268.42	1.86%	50556.44	2947.48	3.06%
Distributor 2 Profit	31463.07	1424.36	2.52%	19056.10	2256.55	6.27%
Distributor 3 Revenue	68211.65	1388.62	1.08%	69095.57	969.62	0.71%
Distributor 3 Cost	35709.06	626.27	0.92%	50724.81	2909.90	3.14%
Distributor 3 Profit	32502.58	995.47	1.62%	18370.76	3030.45	8.85%
Service Level (type 1) for Product 1	96.04%	3.03%	1.61%	98.00%	1.07%	0.58%
Service Level (type 1) for Product 2	94.75%	3.55%	1.92%	97.62%	2.46%	1.25%
Service Level (type 1) for Product 3	93.78%	2.30%	1.24%	98.96%	1.10%	0.61%
Service Level (type 2) for Product 1	88.39%	0.22%	0.13%	91.16%	0.23%	0.13%
Service Level (type 2) for Product 2	88.10%	0.20%	0.12%	91.53%	0.22%	0.13%
Service Level (type 2) for Product 3	87.89%	0.21%	0.13%	91.44%	0.24%	0.14%
Total Revenue	504185.03	4124.61	0.42%	504755.04	3930.00	0.41%
Total Cost	360210.57	7295.75	1.08%	357843.14	4657.11	0.65%
Total Profit	143974.45	6853.87	2.76%	146911.90	5346.37	1.89%

Case #9

Scenario 1	Case Type 8					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	285401.13	3400.11	0.63%	293937.33	2222.62	0.40%
Retailer Cost	241560.78	10031.30	2.09%	204243.24	1471.76	0.39%
Retailer Profit	43840.35	9400.98	9.02%	89694.09	778.50	0.44%
Distributor 1 Revenue	66029.90	1340.33	1.10%	68238.12	889.31	0.66%
Distributor 1 Cost	34238.55	779.23	1.20%	42153.16	2118.43	2.58%
Distributor 1 Profit	31791.35	850.44	1.46%	26084.97	1701.55	3.39%
Distributor 2 Revenue	63842.58	1463.77	1.18%	68007.41	1175.14	0.92%
Distributor 2 Cost	34165.06	973.93	1.50%	41724.64	1579.09	2.01%
Distributor 2 Profit	29677.52	977.28	1.72%	26282.77	1178.37	2.27%
Distributor 3 Revenue	67592.17	1900.68	1.42%	68399.83	1272.59	0.99%
Distributor 3 Cost	36199.08	1227.96	1.82%	43254.18	3104.02	3.73%
Distributor 3 Profit	31393.08	1192.68	2.06%	25145.65	2554.85	5.17%
Service Level (type 1) for Product 1	84.27%	2.84%	1.77%	94.56%	2.08%	1.11%
Service Level (type 1) for Product 2	83.83%	3.89%	2.41%	94.93%	2.53%	1.35%
Service Level (type 1) for Product 3	88.11%	3.63%	2.15%	93.92%	2.56%	1.36%
Service Level (type 2) for Product 1	89.71%	0.07%	0.04%	91.90%	0.11%	0.06%
Service Level (type 2) for Product 2	89.66%	0.10%	0.06%	91.72%	0.09%	0.05%
Service Level (type 2) for Product 3	88.93%	0.03%	0.02%	92.21%	0.11%	0.06%
Total Revenue	482865.78	5848.74	0.61%	498582.70	3878.93	0.39%
Total Cost	346163.47	9998.25	1.56%	331375.22	4584.30	0.74%
Total Profit	136702.31	9022.78	3.33%	167207.47	4023.26	1.30%

Case #10

Scenario 1	Case Type 9					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	294208.67	3383.33	0.64%	298097.33	2588.73	0.48%
Retailer Cost	248481.00	7730.44	1.72%	196671.60	1720.19	0.48%
Retailer Profit	45727.67	6258.80	7.58%	101425.73	907.30	0.50%
Distributor 1 Revenue	67673.67	1606.91	1.32%	69015.33	1188.47	0.95%
Distributor 1 Cost	35745.80	1106.84	1.71%	45088.70	2225.32	2.73%
Distributor 1 Profit	31927.87	1127.74	1.96%	23926.63	1685.87	3.90%
Distributor 2 Revenue	67366.60	1694.17	1.39%	68472.13	1136.07	0.92%
Distributor 2 Cost	36118.33	1408.13	2.16%	45810.10	3603.22	4.36%
Distributor 2 Profit	31248.27	992.91	1.76%	22662.03	3191.05	7.80%
Distributor 3 Revenue	67568.20	1392.47	1.14%	68791.33	907.19	0.73%
Distributor 3 Cost	35538.13	1023.95	1.60%	45778.20	2418.77	2.93%
Distributor 3 Profit	32030.07	1070.07	1.85%	23013.13	2443.83	5.88%
Service Level (type 1) for Product 1	93.86%	3.16%	1.86%	97.75%	1.98%	1.12%
Service Level (type 1) for Product 2	93.83%	3.08%	1.82%	97.26%	2.14%	1.22%
Service Level (type 1) for Product 3	93.78%	3.02%	1.78%	97.68%	1.60%	0.91%
Service Level (type 2) for Product 1	89.27%	0.16%	0.10%	92.19%	0.18%	0.11%
Service Level (type 2) for Product 2	89.30%	0.16%	0.10%	92.14%	0.17%	0.10%
Service Level (type 2) for Product 3	89.41%	0.15%	0.09%	92.08%	0.18%	0.11%
Total Revenue	496817.13	5802.26	0.65%	504376.13	4391.55	0.48%
Total Cost	355883.27	9226.13	1.44%	333348.60	5771.75	0.96%
Total Profit	140933.87	7159.09	2.81%	171027.53	4672.94	1.51%

Case #11

Scenario 1	Case Type 10					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	274420.00	4641.32	0.94%	264041.33	5340.10	1.12%
Retailer Cost	220765.00	3659.72	0.92%	190302.43	3206.98	0.93%
Retailer Profit	53655.00	4485.58	4.63%	73738.90	2178.20	1.64%
Distributor 1 Revenue	63331.33	1592.32	1.39%	61934.13	1686.63	1.51%
Distributor 1 Cost	34717.00	1044.53	1.67%	35011.10	880.62	1.39%
Distributor 1 Profit	28614.33	985.83	1.91%	26923.03	815.73	1.68%
Distributor 2 Revenue	62961.27	2070.09	1.82%	61906.13	2008.66	1.80%
Distributor 2 Cost	34720.67	1577.47	2.52%	34948.60	1076.37	1.71%
Distributor 2 Profit	28240.60	1517.40	2.98%	26957.53	939.76	1.93%
Distributor 3 Revenue	62320.07	2635.26	2.34%	60877.60	2604.74	2.37%
Distributor 3 Cost	33999.73	1512.56	2.46%	34431.63	1323.15	2.13%
Distributor 3 Profit	28320.33	1514.35	2.96%	26445.97	1288.55	2.70%
Service Level (type 1) for Product 1	77.81%	3.24%	2.30%	70.81%	3.37%	2.63%
Service Level (type 1) for Product 2	76.87%	3.86%	2.78%	70.75%	3.75%	2.94%
Service Level (type 1) for Product 3	76.20%	4.17%	3.03%	69.91%	3.92%	3.11%
Service Level (type 2) for Product 1	88.45%	0.15%	0.09%	90.42%	0.31%	0.19%
Service Level (type 2) for Product 2	88.37%	0.16%	0.10%	90.33%	0.30%	0.18%
Service Level (type 2) for Product 3	88.57%	0.19%	0.12%	90.47%	0.34%	0.21%
Total Revenue	463032.67	7898.62	0.94%	448759.20	9181.85	1.13%
Total Cost	324202.40	4291.64	0.73%	294693.77	5188.62	0.98%
Total Profit	138830.27	5409.98	2.16%	154065.43	4008.64	1.44%

Case #12

Scenario 2	Base Case					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	420634.87	9884.80	1.30%	418583.80	10613.04	1.40%
Retailer Cost	322464.05	7551.69	1.30%	297224.15	5673.22	1.06%
Retailer Profit	98170.82	2655.34	1.50%	121359.65	5040.98	2.30%
Distributor 1 Revenue	98425.60	3794.25	2.14%	99941.10	3500.16	1.94%
Distributor 1 Cost	51138.23	2321.66	2.51%	51613.03	2206.37	2.37%
Distributor 1 Profit	47287.37	2432.58	2.85%	48328.07	1646.87	1.89%
Distributor 2 Revenue	97998.88	3775.43	2.13%	97849.92	4478.35	2.53%
Distributor 2 Cost	52171.05	1950.39	2.07%	51481.05	3092.76	3.33%
Distributor 2 Profit	45827.83	2352.66	2.84%	46368.87	1584.76	1.89%
Distributor 3 Revenue	93949.80	3646.05	2.15%	93322.60	3544.56	2.10%
Distributor 3 Cost	52353.83	2378.96	2.52%	49432.87	2445.99	2.74%
Distributor 3 Profit	41595.97	2444.86	3.26%	43889.73	1183.11	1.49%
Service Level (type 1) for Product 1	76.76%	5.78%	4.17%	74.89%	6.84%	5.06%
Service Level (type 1) for Product 2	78.17%	7.17%	5.08%	76.13%	8.08%	5.88%
Service Level (type 1) for Product 3	75.76%	6.18%	4.52%	73.36%	6.64%	5.02%
Service Level (type 2) for Product 1	83.61%	0.43%	0.28%	82.51%	0.47%	0.31%
Service Level (type 2) for Product 2	83.57%	0.61%	0.40%	82.01%	0.56%	0.37%
Service Level (type 2) for Product 3	81.36%	0.77%	0.52%	79.48%	0.75%	0.52%
Total Revenue	711009.15	16828.79	1.31%	709697.42	18129.77	1.41%
Total Cost	478127.17	11347.92	1.31%	449751.10	11617.01	1.43%
Total Profit	232881.98	6979.01	1.66%	259946.32	6610.46	1.41%

Case #13

Scenario 2	Case Type 1					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	424779.80	9636.48	1.26%	420851.40	10250.55	1.35%
Retailer Cost	326508.07	12041.85	2.04%	293859.19	6923.07	1.30%
Retailer Profit	98271.73	4219.70	2.38%	126992.21	3332.26	1.45%
Distributor 1 Revenue	98765.80	4242.07	2.38%	99277.50	4026.72	2.25%
Distributor 1 Cost	57943.05	2198.89	2.10%	56039.30	3904.79	3.86%
Distributor 1 Profit	40822.75	3279.67	4.45%	43238.20	1193.71	1.53%
Distributor 2 Revenue	97582.24	2772.39	1.57%	97245.12	2863.35	1.63%
Distributor 2 Cost	59245.25	1550.30	1.45%	56059.15	2751.43	2.72%
Distributor 2 Profit	38336.99	2377.17	3.43%	41185.97	1266.12	1.70%
Distributor 3 Revenue	96937.40	3272.90	1.87%	96203.80	4364.70	2.51%
Distributor 3 Cost	63647.40	5219.86	4.54%	57411.80	4753.05	4.59%
Distributor 3 Profit	33290.00	3390.39	5.64%	38792.00	2080.79	2.97%
Service Level (type 1) for Product 1	77.53%	7.34%	5.25%	75.45%	8.29%	6.09%
Service Level (type 1) for Product 2	78.37%	4.97%	3.51%	75.92%	5.88%	4.29%
Service Level (type 1) for Product 3	79.14%	6.69%	4.68%	77.15%	7.95%	5.71%
Service Level (type 2) for Product 1	83.61%	0.16%	0.10%	82.51%	0.17%	0.11%
Service Level (type 2) for Product 2	83.57%	0.17%	0.11%	82.01%	0.20%	0.13%
Service Level (type 2) for Product 3	81.36%	0.28%	0.19%	79.48%	0.31%	0.22%
Total Revenue	718065.24	16411.92	1.27%	713577.82	17522.98	1.36%
Total Cost	507343.77	16964.00	1.85%	463369.44	16048.77	1.92%
Total Profit	210721.47	6553.89	1.72%	250208.38	3221.59	0.71%

Case #14

Scenario 2	Case Type 2					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	455432.21	7126.50	0.79%	449775.12	7132.76	0.82%
Retailer Cost	416347.31	5796.73	0.73%	426305.33	6254.31	0.75%
Retailer Profit	39084.90	6474.53	9.82%	23469.78	5397.03	8.92%
Distributor 1 Revenue	98882.55	2346.68	1.21%	99933.04	2417.74	1.24%
Distributor 1 Cost	46609.28	1017.73	1.18%	48306.35	1168.39	1.30%
Distributor 1 Profit	52273.28	1392.25	1.40%	51626.69	1278.88	1.24%
Distributor 2 Revenue	98020.46	2780.36	1.50%	96526.00	3240.63	1.76%
Distributor 2 Cost	46045.19	1385.52	1.55%	47076.94	1512.21	1.76%
Distributor 2 Profit	51975.26	1443.12	1.49%	49449.06	1662.55	1.71%
Distributor 3 Revenue	96203.46	2589.64	1.40%	94514.38	2685.72	1.49%
Distributor 3 Cost	46222.04	1213.56	1.38%	46245.83	1240.41	1.43%
Distributor 3 Profit	49981.43	1405.91	1.50%	48268.55	1404.57	1.45%
Service Level (type 1) for Product 1	77.17%	5.20%	3.55%	73.14%	5.40%	3.73%
Service Level (type 1) for Product 2	78.98%	5.19%	3.37%	73.49%	6.07%	4.36%
Service Level (type 1) for Product 3	79.37%	4.39%	2.92%	73.29%	4.63%	3.38%
Service Level (type 2) for Product 1	84.03%	0.08%	0.05%	82.63%	0.11%	0.07%
Service Level (type 2) for Product 2	82.85%	0.06%	0.04%	81.22%	0.13%	0.08%
Service Level (type 2) for Product 3	82.27%	0.09%	0.06%	79.85%	0.09%	0.06%
Total Revenue	748538.68	12185.58	0.82%	740748.53	11958.34	0.83%
Total Cost	555223.82	7009.88	0.68%	567934.45	8691.52	0.77%
Total Profit	193314.87	8798.17	2.31%	172814.08	6221.92	1.91%

Case #15

Scenario 2	Case Type 3					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	450000.00	0.00	0.00%	450000.00	0.00	0.00%
Retailer Cost	335050.00	0.00	0.00%	313740.00	0.00	0.00%
Retailer Profit	114950.00	0.00	0.00%	136260.00	0.00	0.00%
Distributor 1 Revenue	104370.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 1 Cost	51470.00	0.00	0.00%	59010.00	0.00	0.00%
Distributor 1 Profit	52900.00	0.00	0.00%	45570.00	0.00	0.00%
Distributor 2 Revenue	104160.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 2 Cost	52705.00	0.00	0.00%	61520.00	0.00	0.00%
Distributor 2 Profit	51455.00	0.00	0.00%	43060.00	0.00	0.00%
Distributor 3 Revenue	104020.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 3 Cost	53950.00	0.00	0.00%	64030.00	0.00	0.00%
Distributor 3 Profit	50070.00	0.00	0.00%	40550.00	0.00	0.00%
Service Level (type 1) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Total Revenue	762550.00	0.00	0.00%	763740.00	0.00	0.00%
Total Cost	493175.00	0.00	0.00%	498300.00	0.00	0.00%
Total Profit	269375.00	0.00	0.00%	265440.00	0.00	0.00%

Case #16

Scenario 2	Case Type 4					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	412158.53	16622.78	2.23%	415530.13	17831.34	2.38%
Retailer Cost	322890.83	12489.25	2.14%	296348.65	10232.31	1.91%
Retailer Profit	89267.70	4603.88	2.86%	119181.48	7791.87	3.62%
Distributor 1 Revenue	97795.60	8474.45	4.80%	100667.70	7495.57	4.12%
Distributor 1 Cost	52455.50	4480.64	4.73%	53047.77	5593.99	5.84%
Distributor 1 Profit	45340.10	4488.87	5.48%	47619.93	2552.98	2.97%
Distributor 2 Revenue	93214.80	6287.44	3.74%	93977.52	5987.40	3.53%
Distributor 2 Cost	51159.72	3522.53	3.81%	49670.81	3937.98	4.39%
Distributor 2 Profit	42055.08	3073.44	4.05%	44306.71	2342.26	2.93%
Distributor 3 Revenue	93461.20	6429.92	3.81%	94428.60	6669.30	3.91%
Distributor 3 Cost	57164.47	7129.27	6.91%	51786.03	4809.40	5.14%
Distributor 3 Profit	36296.73	4396.20	6.71%	42642.57	2591.09	3.37%
Service Level (type 1) for Product 1	70.74%	11.83%	9.26%	72.04%	10.81%	8.31%
Service Level (type 1) for Product 2	69.72%	7.89%	6.27%	69.13%	8.33%	6.67%
Service Level (type 1) for Product 3	72.38%	9.50%	7.27%	72.66%	9.29%	7.08%
Service Level (type 2) for Product 1	81.61%	0.46%	0.31%	81.68%	0.33%	0.22%
Service Level (type 2) for Product 2	81.31%	0.51%	0.35%	80.30%	0.43%	0.30%
Service Level (type 2) for Product 3	80.26%	0.41%	0.28%	78.80%	0.26%	0.19%
Total Revenue	696630.13	28332.50	2.25%	704603.95	30545.66	2.40%
Total Cost	483670.52	20000.75	2.29%	450853.27	20033.67	2.46%
Total Profit	212959.61	11136.20	2.90%	253750.69	10694.69	2.33%

Case #17

Scenario 2	Case Type 5					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	402752.93	8490.22	1.17%	420332.07	7358.66	0.97%
Retailer Cost	306260.71	5573.07	1.01%	298228.37	3974.24	0.74%
Retailer Profit	96492.22	2980.16	1.71%	122103.70	3734.79	1.69%
Distributor 1 Revenue	92836.80	2764.85	1.65%	98471.10	2788.81	1.57%
Distributor 1 Cost	50984.70	1777.39	1.93%	50751.00	1941.82	2.12%
Distributor 1 Profit	41852.10	2068.71	2.74%	47720.10	1095.79	1.27%
Distributor 2 Revenue	94003.28	6010.84	3.54%	98070.00	5652.43	3.19%
Distributor 2 Cost	53011.14	3155.26	3.30%	51720.23	3497.31	3.75%
Distributor 2 Profit	40992.14	3203.32	4.33%	46349.77	2459.38	2.94%
Distributor 3 Revenue	91986.53	3191.18	1.92%	95855.20	3378.19	1.95%
Distributor 3 Cost	56308.20	3912.19	3.85%	51144.47	2659.23	2.88%
Distributor 3 Profit	35678.33	2135.39	3.31%	44710.73	1321.36	1.64%
Service Level (type 1) for Product 1	67.04%	2.99%	2.47%	74.66%	6.99%	5.18%
Service Level (type 1) for Product 2	71.04%	6.23%	4.86%	76.19%	7.45%	5.42%
Service Level (type 1) for Product 3	71.33%	4.30%	3.34%	76.02%	6.91%	5.04%
Service Level (type 2) for Product 1	82.42%	0.30%	0.20%	82.94%	0.10%	0.07%
Service Level (type 2) for Product 2	82.24%	0.27%	0.18%	81.56%	0.10%	0.07%
Service Level (type 2) for Product 3	81.28%	0.25%	0.17%	80.27%	0.07%	0.05%
Total Revenue	681579.55	14487.87	1.18%	712728.37	12582.01	0.98%
Total Cost	466564.75	9614.57	1.14%	451844.07	8135.02	1.00%
Total Profit	215014.79	6630.98	1.71%	260884.30	4693.55	1.00%

Case #18

Scenario 2	Case Type 6					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	410187.73	6642.17	0.90%	435944.33	4578.20	0.58%
Retailer Cost	314664.29	4101.35	0.72%	307009.23	3150.00	0.57%
Retailer Profit	95523.45	2661.89	1.54%	128935.10	1544.69	0.66%
Distributor 1 Revenue	95972.80	2780.89	1.60%	102191.60	1834.72	0.99%
Distributor 1 Cost	52180.03	1386.52	1.47%	53863.27	1046.42	1.08%
Distributor 1 Profit	43792.77	1859.14	2.35%	48328.33	887.30	1.02%
Distributor 2 Revenue	95371.92	3239.99	1.88%	101281.60	1796.70	0.98%
Distributor 2 Cost	53487.84	2543.68	2.63%	54863.27	1292.67	1.30%
Distributor 2 Profit	41884.08	1583.76	2.09%	46418.33	798.26	0.95%
Distributor 3 Revenue	91702.80	2405.86	1.45%	100277.33	1911.18	1.06%
Distributor 3 Cost	59789.67	3905.61	3.62%	55974.13	1333.55	1.32%
Distributor 3 Profit	31913.13	4487.27	7.79%	44303.20	892.32	1.12%
Service Level (type 1) for Product 1	69.59%	4.07%	3.24%	84.21%	1.48%	0.97%
Service Level (type 1) for Product 2	71.88%	4.26%	3.28%	84.49%	2.35%	1.54%
Service Level (type 1) for Product 3	70.55%	4.26%	3.34%	85.33%	2.23%	1.45%
Service Level (type 2) for Product 1	84.65%	0.24%	0.15%	84.98%	0.09%	0.06%
Service Level (type 2) for Product 2	84.48%	0.22%	0.14%	83.64%	0.10%	0.07%
Service Level (type 2) for Product 3	83.47%	0.26%	0.17%	82.46%	0.14%	0.09%
Total Revenue	693235.25	11303.50	0.90%	739694.87	7834.27	0.59%
Total Cost	480121.83	8580.95	0.99%	471709.90	5081.77	0.60%
Total Profit	213113.43	6069.11	1.58%	267984.97	2934.49	0.61%

Case #19

Scenario 2	Case Type 7					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	441668.80	8065.39	1.01%	445902.87	4456.26	0.55%
Retailer Cost	349259.26	9274.83	1.47%	310724.89	2955.94	0.53%
Retailer Profit	92409.54	3185.60	1.91%	135177.98	1567.72	0.64%
Distributor 1 Revenue	101987.20	5772.03	3.13%	103478.20	4139.29	2.22%
Distributor 1 Cost	50703.90	2432.76	2.66%	65382.27	6315.22	5.35%
Distributor 1 Profit	51283.30	3442.08	3.72%	38095.93	4075.70	5.93%
Distributor 2 Revenue	100901.36	2276.33	1.25%	102665.92	1518.37	0.82%
Distributor 2 Cost	50213.64	1450.43	1.60%	61902.71	3198.81	2.86%
Distributor 2 Profit	50687.72	1482.70	1.62%	40763.21	2852.59	3.88%
Distributor 3 Revenue	102404.87	3298.04	1.78%	103695.67	2424.03	1.29%
Distributor 3 Cost	52710.53	2584.85	2.72%	64114.53	3952.39	3.41%
Distributor 3 Profit	49694.33	2303.31	2.57%	39581.13	2905.06	4.06%
Service Level (type 1) for Product 1	90.97%	7.57%	4.61%	95.81%	5.72%	3.31%
Service Level (type 1) for Product 2	89.95%	4.15%	2.55%	94.94%	2.66%	1.55%
Service Level (type 1) for Product 3	92.49%	5.26%	3.15%	95.89%	2.04%	1.18%
Service Level (type 2) for Product 1	84.65%	0.22%	0.14%	85.63%	0.27%	0.18%
Service Level (type 2) for Product 2	84.48%	0.18%	0.12%	84.32%	0.27%	0.18%
Service Level (type 2) for Product 3	83.46%	0.25%	0.17%	83.23%	0.31%	0.21%
Total Revenue	746962.23	13803.39	1.02%	755742.65	7724.46	0.57%
Total Cost	502887.33	11280.91	1.24%	502124.40	9360.80	1.03%
Total Profit	244074.89	5616.55	1.27%	253618.25	4999.18	1.09%

Case #20

Scenario 2	Case Type 8					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	414521.13	8007.71	1.07%	438453.73	7322.51	0.92%
Retailer Cost	319446.16	5163.49	0.90%	317899.34	9563.43	1.67%
Retailer Profit	95074.97	2982.90	1.74%	120554.39	8549.42	3.93%
Distributor 1 Revenue	98945.00	3647.14	2.04%	104568.80	2814.89	1.49%
Distributor 1 Cost	49119.27	1333.52	1.50%	56546.33	2458.02	2.41%
Distributor 1 Profit	49825.73	2563.03	2.85%	48022.47	1719.35	1.98%
Distributor 2 Revenue	97012.16	3896.03	2.22%	101950.24	3776.50	2.05%
Distributor 2 Cost	48833.75	2361.22	2.68%	55168.83	3154.04	3.17%
Distributor 2 Profit	48178.41	1849.88	2.13%	46781.41	1099.64	1.30%
Distributor 3 Revenue	92316.93	3261.55	1.96%	98684.13	3529.07	1.98%
Distributor 3 Cost	50864.27	2654.30	2.89%	53565.67	2707.38	2.80%
Distributor 3 Profit	41452.67	3346.49	4.47%	45118.47	1141.72	1.40%
Service Level (type 1) for Product 1	72.19%	4.94%	3.79%	89.10%	4.98%	3.10%
Service Level (type 1) for Product 2	73.75%	5.51%	4.14%	87.64%	5.78%	3.65%
Service Level (type 1) for Product 3	72.11%	5.23%	4.02%	85.66%	5.85%	3.78%
Service Level (type 2) for Product 1	84.67%	0.11%	0.07%	86.24%	0.16%	0.10%
Service Level (type 2) for Product 2	84.47%	0.11%	0.07%	84.93%	0.14%	0.09%
Service Level (type 2) for Product 3	83.52%	0.17%	0.11%	83.85%	0.10%	0.07%
Total Revenue	702795.23	13664.49	1.08%	743656.91	12638.23	0.94%
Total Cost	468263.44	8133.37	0.96%	483180.17	12280.72	1.41%
Total Profit	234531.79	6818.22	1.61%	260476.74	8920.71	1.90%

Case #21

Scenario 2	Case Type 9					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	439100.80	6740.74	0.85%	444668.67	4251.75	0.53%
Retailer Cost	345830.55	9383.70	1.50%	309626.51	2824.74	0.51%
Retailer Profit	93270.25	4242.81	2.52%	135042.15	1542.86	0.63%
Distributor 1 Revenue	102301.50	3084.91	1.67%	104344.80	2351.37	1.25%
Distributor 1 Cost	50546.60	1742.07	1.91%	60674.53	3892.73	3.55%
Distributor 1 Profit	51754.90	1678.88	1.80%	43670.27	3060.57	3.88%
Distributor 2 Revenue	101123.68	3793.14	2.08%	102764.48	3138.04	1.69%
Distributor 2 Cost	50803.98	2134.64	2.33%	59336.85	3705.17	3.46%
Distributor 2 Profit	50319.70	1857.36	2.04%	43427.63	2131.63	2.72%
Distributor 3 Revenue	99994.53	3080.76	1.71%	101620.40	2537.89	1.38%
Distributor 3 Cost	51066.57	1981.84	2.15%	58686.53	4412.55	4.16%
Distributor 3 Profit	48927.97	1877.43	2.13%	42933.87	2711.63	3.50%
Service Level (type 1) for Product 1	90.18%	6.91%	4.25%	96.78%	2.88%	1.65%
Service Level (type 1) for Product 2	89.37%	6.12%	3.79%	95.46%	3.93%	2.28%
Service Level (type 1) for Product 3	88.86%	6.59%	4.11%	94.78%	3.85%	2.25%
Service Level (type 2) for Product 1	84.79%	0.18%	0.12%	86.87%	0.22%	0.14%
Service Level (type 2) for Product 2	84.53%	0.14%	0.09%	85.51%	0.22%	0.14%
Service Level (type 2) for Product 3	83.55%	0.13%	0.09%	84.44%	0.21%	0.14%
Total Revenue	742520.51	11480.49	0.86%	753398.35	7314.39	0.54%
Total Cost	498247.69	12640.07	1.41%	488324.43	9537.42	1.08%
Total Profit	244272.82	4477.54	1.02%	265073.91	5035.00	1.05%

Case #22

Scenario 2	Case Type 10					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	410415.60	3566.03	0.48%	412416.13	8813.39	1.18%
Retailer Cost	313601.32	3326.71	0.59%	294400.43	4364.13	0.82%
Retailer Profit	96814.28	1801.66	1.03%	118015.71	4751.83	2.23%
Distributor 1 Revenue	96534.90	3809.03	2.19%	98942.90	3735.78	2.09%
Distributor 1 Cost	50257.17	1809.07	1.99%	51184.00	2122.30	2.30%
Distributor 1 Profit	46277.73	3041.53	3.64%	47758.90	1753.33	2.03%
Distributor 2 Revenue	95044.32	2874.64	1.68%	95754.96	3580.64	2.07%
Distributor 2 Cost	50658.03	2600.58	2.84%	50438.87	2050.27	2.25%
Distributor 2 Profit	44386.29	2801.25	3.50%	45316.09	1816.05	2.22%
Distributor 3 Revenue	91960.40	3312.20	1.99%	93510.67	4609.69	2.73%
Distributor 3 Cost	55762.97	5032.19	5.00%	49951.77	3113.31	3.45%
Distributor 3 Profit	36197.43	2871.88	4.39%	43558.90	1911.94	2.43%
Service Level (type 1) for Product 1	70.22%	3.74%	2.95%	73.28%	6.26%	4.73%
Service Level (type 1) for Product 2	71.87%	3.13%	2.41%	74.23%	5.85%	4.37%
Service Level (type 1) for Product 3	71.69%	3.74%	2.89%	73.71%	7.31%	5.49%
Service Level (type 2) for Product 1	84.93%	0.15%	0.10%	86.28%	1.06%	0.68%
Service Level (type 2) for Product 2	84.69%	0.20%	0.13%	84.92%	1.08%	0.70%
Service Level (type 2) for Product 3	83.64%	0.30%	0.20%	83.72%	1.09%	0.72%
Total Revenue	693955.22	5864.24	0.47%	700624.66	14249.03	1.13%
Total Cost	470279.49	6484.55	0.76%	445975.07	8227.38	1.02%
Total Profit	223675.73	5567.29	1.38%	254649.59	6184.03	1.34%

Case #23

Scenario 3	Base Case					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	444943.44	2573.91	0.30%	446200.01	1412.49	0.17%
Retailer Cost	364020.53	14709.20	2.11%	315907.96	398.33	0.07%
Retailer Profit	80922.91	16842.28	9.66%	130292.04	1310.07	0.51%
Distributor 1 Revenue	104189.90	205.37	0.10%	103643.00	0.00	0.00%
Distributor 1 Cost	51823.84	809.52	0.84%	58407.45	3705.19	3.39%
Distributor 1 Profit	52366.06	753.59	0.75%	45235.55	3748.53	4.23%
Distributor 2 Revenue	104227.73	209.32	0.10%	104686.81	0.00	0.00%
Distributor 2 Cost	52764.23	702.74	0.68%	62147.45	4882.57	3.97%
Distributor 2 Profit	51463.50	613.71	0.62%	42539.36	4849.44	5.99%
Distributor 3 Revenue	103805.46	204.29	0.10%	103961.58	0.00	0.00%
Distributor 3 Cost	55187.97	1836.93	1.75%	63148.09	3309.55	2.77%
Distributor 3 Profit	48617.49	1702.36	1.92%	40813.49	3422.49	4.29%
Service Level (type 1) for Product 1	76.50%	2.29%	1.55%	76.16%	2.14%	1.44%
Service Level (type 1) for Product 2	76.61%	2.94%	1.98%	76.10%	2.03%	1.33%
Service Level (type 1) for Product 3	78.28%	1.36%	0.92%	75.21%	2.45%	1.60%
Service Level (type 2) for Product 1	77.14%	0.15%	0.10%	75.64%	0.06%	0.04%
Service Level (type 2) for Product 2	76.32%	0.15%	0.09%	76.76%	0.08%	0.06%
Service Level (type 2) for Product 3	77.48%	0.07%	0.05%	76.57%	0.15%	0.11%
Total Revenue	757166.54	2625.67	0.19%	763737.84	1450.63	0.10%
Total Cost	523796.58	15445.38	1.59%	498261.11	8002.93	0.87%
Total Profit	233369.96	17451.74	4.02%	265476.73	9006.10	1.75%

Case #24

Scenario 3	Case Type 1					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	445804.47	2016.62	0.30%	450483.99	2289.62	0.36%
Retailer Cost	388811.52	7012.43	1.22%	314774.06	63.64	0.01%
Retailer Profit	56992.95	8121.15	9.41%	135709.93	2380.16	1.20%
Distributor 1 Revenue	105130.52	173.79	0.11%	103916.45	0.00	0.00%
Distributor 1 Cost	58835.48	2556.04	3.01%	70649.27	5358.16	5.07%
Distributor 1 Profit	46295.04	2528.20	3.84%	33267.18	5509.90	8.23%
Distributor 2 Revenue	103387.67	93.17	0.06%	105035.95	0.00	0.00%
Distributor 2 Cost	59444.39	807.57	0.94%	72351.35	4487.06	4.11%
Distributor 2 Profit	43943.28	761.64	1.25%	32684.60	4350.41	7.05%
Distributor 3 Revenue	104537.97	119.41	0.08%	104378.84	0.00	0.00%
Distributor 3 Cost	64160.35	4200.50	4.49%	76181.96	6180.13	5.87%
Distributor 3 Profit	40377.63	4195.31	7.21%	28196.88	6324.79	8.47%
Service Level (type 1) for Product 1	75.65%	1.88%	1.70%	76.59%	1.91%	1.71%
Service Level (type 1) for Product 2	75.73%	1.73%	1.65%	75.33%	1.78%	1.65%
Service Level (type 1) for Product 3	75.35%	1.67%	1.49%	76.19%	1.35%	1.20%
Service Level (type 2) for Product 1	78.05%	0.06%	0.05%	76.18%	0.05%	0.05%
Service Level (type 2) for Product 2	76.07%	0.03%	0.03%	75.89%	0.06%	0.06%
Service Level (type 2) for Product 3	77.52%	0.10%	0.09%	75.81%	0.05%	0.05%
Total Revenue	758860.63	1868.04	0.18%	763815.23	2336.21	0.21%
Total Cost	571251.74	8474.03	1.06%	533956.64	11882.91	1.54%
Total Profit	187608.89	10145.40	3.71%	229858.59	13384.54	4.06%

Case #25

Scenario 3	Case Type 2					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	447925.33	2015.87	0.25%	446731.40	2695.06	0.33%
Retailer Cost	354412.97	7903.30	1.24%	328526.00	11115.84	1.87%
Retailer Profit	93512.37	6616.01	3.92%	118205.40	10428.33	4.89%
Distributor 1 Revenue	104004.60	323.83	0.17%	104580.00	0.00	0.00%
Distributor 1 Cost	48284.94	166.25	0.19%	51000.14	918.44	1.00%
Distributor 1 Profit	55719.66	464.82	0.46%	53579.86	918.44	0.95%
Distributor 2 Revenue	104094.48	144.39	0.08%	104580.00	0.00	0.00%
Distributor 2 Cost	48845.92	237.25	0.27%	51697.59	1174.11	1.26%
Distributor 2 Profit	55248.56	310.35	0.31%	52882.41	1174.11	1.23%
Distributor 3 Revenue	103828.20	215.31	0.11%	104580.00	0.00	0.00%
Distributor 3 Cost	49965.54	642.26	0.71%	52239.96	1332.74	1.41%
Distributor 3 Profit	53862.66	613.70	0.63%	52340.04	1332.74	1.41%
Service Level (type 1) for Product 1	76.63%	2.69%	1.95%	75.85%	3.27%	2.39%
Service Level (type 1) for Product 2	76.81%	2.55%	1.84%	76.49%	2.94%	2.13%
Service Level (type 1) for Product 3	75.44%	2.96%	2.18%	76.34%	2.48%	1.80%
Service Level (type 2) for Product 1	77.20%	0.06%	0.04%	76.33%	0.09%	0.06%
Service Level (type 2) for Product 2	76.74%	0.08%	0.06%	76.44%	0.09%	0.07%
Service Level (type 2) for Product 3	76.80%	0.11%	0.08%	76.05%	0.10%	0.07%
Total Revenue	759852.61	2171.43	0.16%	760471.40	2695.06	0.20%
Total Cost	501509.37	8000.81	0.88%	483463.69	9242.21	1.06%
Total Profit	258343.25	6857.11	1.47%	277007.71	9015.65	1.80%

Case #26

Scenario 3	Case Type 3					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	450000.00	0.00	0.00%	449911.00	30.78	0.00%
Retailer Cost	325050.00	0.00	0.00%	313793.87	6.45	0.00%
Retailer Profit	124950.00	0.00	0.00%	136117.13	30.05	0.01%
Distributor 1 Revenue	104370.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 1 Cost	51470.00	0.00	0.00%	56487.13	247.79	0.24%
Distributor 1 Profit	52900.00	0.00	0.00%	48092.87	247.79	0.29%
Distributor 2 Revenue	104160.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 2 Cost	52705.00	0.00	0.00%	55265.07	2.18	0.00%
Distributor 2 Profit	51455.00	0.00	0.00%	49314.93	2.18	0.00%
Distributor 3 Revenue	104020.00	0.00	0.00%	104580.00	0.00	0.00%
Distributor 3 Cost	53950.00	0.00	0.00%	56451.10	4.36	0.00%
Distributor 3 Profit	50070.00	0.00	0.00%	48128.90	4.36	0.01%
Service Level (type 1) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 1) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 1	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 2	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Service Level (type 2) for Product 3	100.00%	0.00%	0.00%	100.00%	0.00%	0.00%
Total Revenue	762550.00	0.00	0.00%	763651.00	30.78	0.00%
Total Cost	483175.00	0.00	0.00%	481997.17	247.99	0.03%
Total Profit	279375.00	0.00	0.00%	281653.83	278.73	0.05%

Case #27

Scenario 3	Case Type 4					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	442631.05	3563.09	0.41%	447309.01	3025.93	0.34%
Retailer Cost	374675.41	11843.20	1.66%	313942.06	662.85	0.11%
Retailer Profit	67955.64	14532.79	9.82%	133366.95	2902.97	1.18%
Distributor 1 Revenue	104326.25	226.18	0.12%	103645.56	0.00	0.00%
Distributor 1 Cost	53612.14	2882.72	2.79%	61585.23	4246.61	3.57%
Distributor 1 Profit	50714.11	2768.02	2.87%	42060.33	4025.23	5.03%
Distributor 2 Revenue	102853.68	296.82	0.15%	105248.77	0.00	0.00%
Distributor 2 Cost	53468.19	1180.77	1.13%	67883.07	4811.60	3.64%
Distributor 2 Profit	49385.49	998.59	1.05%	37365.69	4636.21	6.61%
Distributor 3 Revenue	103868.79	477.48	0.24%	105079.82	0.00	0.00%
Distributor 3 Cost	56986.08	4032.25	3.65%	77213.82	5036.79	3.35%
Distributor 3 Profit	46882.71	3697.48	4.19%	27866.00	4983.00	8.82%
Service Level (type 1) for Product 1	66.87%	3.88%	3.09%	67.16%	3.54%	2.73%
Service Level (type 1) for Product 2	67.48%	3.28%	2.44%	68.30%	3.73%	2.82%
Service Level (type 1) for Product 3	66.88%	3.74%	2.90%	68.46%	3.40%	2.62%
Service Level (type 2) for Product 1	71.69%	0.15%	0.11%	72.08%	0.13%	0.09%
Service Level (type 2) for Product 2	72.26%	0.13%	0.10%	71.74%	0.11%	0.08%
Service Level (type 2) for Product 3	71.72%	0.16%	0.12%	72.11%	0.11%	0.08%
Total Revenue	753679.76	3567.94	0.25%	761283.15	2928.85	0.20%
Total Cost	538741.81	12091.83	1.15%	520624.18	8324.49	0.80%
Total Profit	214937.95	14715.77	3.36%	240658.97	9534.05	2.06%

Case #28

Scenario 3	Case Type 5					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	445626.47	2346.52	0.29%	447476.47	1461.90	0.18%
Retailer Cost	360286.00	9847.37	1.51%	314579.57	370.67	0.07%
Retailer Profit	85340.47	12062.72	7.83%	132896.90	1388.66	0.58%
Distributor 1 Revenue	103975.20	197.03	0.10%	104580.00	0.00	0.00%
Distributor 1 Cost	53764.20	117.69	0.12%	58589.87	4162.97	3.94%
Distributor 1 Profit	50211.00	79.63	0.09%	45990.13	4162.97	5.01%
Distributor 2 Revenue	103840.80	255.16	0.14%	104580.00	0.00	0.00%
Distributor 2 Cost	55648.90	159.11	0.16%	60892.70	4327.52	3.94%
Distributor 2 Profit	48191.90	96.61	0.11%	43687.30	4327.52	5.49%
Distributor 3 Revenue	103653.20	214.58	0.11%	104580.00	0.00	0.00%
Distributor 3 Cost	57475.50	144.85	0.14%	63341.03	4988.31	4.36%
Distributor 3 Profit	46177.70	74.25	0.09%	41238.97	4988.31	6.70%
Service Level (type 1) for Product 1	75.05%	2.59%	1.91%	75.52%	2.42%	1.77%
Service Level (type 1) for Product 2	75.03%	2.63%	1.94%	75.69%	1.70%	1.24%
Service Level (type 1) for Product 3	74.90%	2.34%	1.73%	75.95%	2.31%	1.69%
Service Level (type 2) for Product 1	76.95%	0.03%	0.02%	76.45%	0.03%	0.02%
Service Level (type 2) for Product 2	76.80%	0.03%	0.02%	76.71%	0.03%	0.02%
Service Level (type 2) for Product 3	76.77%	0.04%	0.03%	76.45%	0.02%	0.01%
Total Revenue	757095.67	2318.29	0.17%	761216.47	1461.90	0.11%
Total Cost	527174.60	9887.38	1.04%	497403.17	8450.18	0.94%
Total Profit	229921.07	12059.47	2.90%	263813.30	9553.11	2.01%

Case #29

Scenario 3	Case Type 6					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	445668.01	2508.20	0.30%	449977.22	2254.66	0.26%
Retailer Cost	357324.04	9495.69	1.38%	314977.17	499.38	0.08%
Retailer Profit	88343.96	11434.62	6.65%	135000.05	2119.34	0.81%
Distributor 1 Revenue	103379.94	270.29	0.13%	105154.76	0.00	0.00%
Distributor 1 Cost	53993.77	872.28	0.88%	60482.79	3944.99	3.28%
Distributor 1 Profit	49386.17	782.27	0.81%	44671.97	3837.75	4.52%
Distributor 2 Revenue	103365.74	163.00	0.08%	103259.16	0.00	0.00%
Distributor 2 Cost	56089.81	1105.17	1.03%	63177.63	4364.14	3.52%
Distributor 2 Profit	47275.93	1043.51	1.11%	40081.53	4375.87	5.46%
Distributor 3 Revenue	103257.65	181.30	0.09%	103778.99	0.00	0.00%
Distributor 3 Cost	56999.98	841.73	0.78%	66428.72	5760.25	4.50%
Distributor 3 Profit	46257.67	754.32	0.88%	37350.27	5704.22	7.76%
Service Level (type 1) for Product 1	74.70%	2.81%	1.98%	73.93%	2.93%	2.10%
Service Level (type 1) for Product 2	75.07%	2.44%	1.72%	74.19%	2.54%	1.72%
Service Level (type 1) for Product 3	74.36%	2.83%	2.00%	75.11%	2.47%	1.73%
Service Level (type 2) for Product 1	76.37%	0.03%	0.02%	76.61%	0.03%	0.02%
Service Level (type 2) for Product 2	76.46%	0.01%	0.01%	76.64%	0.04%	0.03%
Service Level (type 2) for Product 3	76.76%	0.03%	0.02%	77.08%	0.04%	0.02%
Total Revenue	755671.34	2648.32	0.18%	762170.13	2142.72	0.15%
Total Cost	524407.61	10021.90	0.97%	505066.31	8175.81	0.83%
Total Profit	231263.72	11703.62	2.61%	257103.82	9584.11	1.92%

Case #30

Scenario 3	Case Type 7					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	448162.86	2451.13	0.28%	445175.40	1661.96	0.19%
Retailer Cost	386880.39	9694.21	1.28%	316234.48	210.19	0.03%
Retailer Profit	61282.47	10879.92	7.88%	128940.92	1566.37	0.59%
Distributor 1 Revenue	104921.82	160.58	0.08%	104688.50	0.00	0.00%
Distributor 1 Cost	51161.53	1343.47	1.36%	71546.26	5595.58	4.09%
Distributor 1 Profit	53760.29	1239.66	1.18%	33142.24	5730.01	7.25%
Distributor 2 Revenue	103790.63	276.50	0.14%	105425.28	0.00	0.00%
Distributor 2 Cost	51093.50	1686.19	1.72%	72760.37	6482.38	4.57%
Distributor 2 Profit	52697.13	1552.74	1.52%	32664.91	6343.36	8.84%
Distributor 3 Revenue	105654.93	142.08	0.07%	104358.92	0.00	0.00%
Distributor 3 Cost	51400.76	1684.41	1.67%	68962.13	5813.54	4.48%
Distributor 3 Profit	54254.17	1607.60	1.57%	35396.79	5872.90	6.86%
Service Level (type 1) for Product 1	79.27%	1.26%	0.83%	79.71%	1.22%	0.79%
Service Level (type 1) for Product 2	78.53%	1.55%	1.04%	78.97%	1.27%	0.88%
Service Level (type 1) for Product 3	78.40%	2.04%	1.37%	78.42%	1.25%	0.82%
Service Level (type 2) for Product 1	76.59%	0.04%	0.03%	76.29%	0.05%	0.03%
Service Level (type 2) for Product 2	77.04%	0.04%	0.03%	76.06%	0.04%	0.03%
Service Level (type 2) for Product 3	76.32%	0.02%	0.01%	75.78%	0.03%	0.02%
Total Revenue	762530.23	2408.87	0.17%	759648.10	1582.33	0.11%
Total Cost	540536.17	10461.58	1.05%	529503.24	12434.21	1.25%
Total Profit	221994.06	11459.75	2.83%	230144.86	13644.29	2.98%

Case #31

Scenario 3	Case Type 8					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	441319.80	2300.08	0.28%	447506.04	2491.23	0.28%
Retailer Cost	365590.96	9775.85	1.41%	311980.81	371.29	0.06%
Retailer Profit	75728.84	11823.99	7.93%	135525.23	2314.03	0.92%
Distributor 1 Revenue	104309.44	211.68	0.10%	104364.16	0.00	0.00%
Distributor 1 Cost	51559.31	588.82	0.57%	62489.68	6378.56	5.55%
Distributor 1 Profit	52750.13	536.31	0.52%	41874.47	6307.44	8.06%
Distributor 2 Revenue	103084.76	220.84	0.11%	104707.96	0.00	0.00%
Distributor 2 Cost	53452.75	1327.27	1.35%	63966.72	5995.28	4.98%
Distributor 2 Profit	49632.01	1221.15	1.23%	40741.25	6012.74	7.31%
Distributor 3 Revenue	103958.49	170.95	0.08%	104573.32	0.00	0.00%
Distributor 3 Cost	55188.27	2628.83	2.51%	65470.45	5689.69	4.33%
Distributor 3 Profit	48770.22	2528.21	2.67%	39102.87	5687.14	7.47%
Service Level (type 1) for Product 1	72.71%	2.50%	1.88%	77.22%	1.98%	1.30%
Service Level (type 1) for Product 2	73.02%	2.55%	1.93%	76.09%	1.98%	1.40%
Service Level (type 1) for Product 3	73.18%	2.09%	1.52%	77.14%	1.84%	1.21%
Service Level (type 2) for Product 1	76.82%	0.06%	0.04%	76.35%	0.02%	0.01%
Service Level (type 2) for Product 2	76.80%	0.07%	0.05%	76.17%	0.01%	0.01%
Service Level (type 2) for Product 3	77.37%	0.05%	0.04%	76.37%	0.01%	0.01%
Total Revenue	752672.49	2376.69	0.17%	761151.48	2601.03	0.18%
Total Cost	525791.28	12129.59	1.20%	503907.65	14822.22	1.47%
Total Profit	226881.20	13489.44	3.14%	257243.82	16523.63	3.28%

Case #32

Scenario 3	Case Type 9					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	452094.01	2281.70	0.28%	445264.13	2225.61	0.26%
Retailer Cost	367937.38	11088.98	1.56%	296824.84	200.71	0.04%
Retailer Profit	84156.63	12472.33	8.20%	148439.29	2112.50	0.71%
Distributor 1 Revenue	104610.71	213.62	0.11%	105112.71	0.00	0.00%
Distributor 1 Cost	51747.64	446.44	0.45%	64216.47	5806.35	4.59%
Distributor 1 Profit	52863.08	390.03	0.39%	40896.24	5808.45	7.50%
Distributor 2 Revenue	104251.64	171.66	0.08%	104178.45	0.00	0.00%
Distributor 2 Cost	53370.97	1142.61	1.15%	66162.52	6478.72	5.27%
Distributor 2 Profit	50880.66	1080.46	1.08%	38015.93	6525.05	9.18%
Distributor 3 Revenue	103601.45	166.54	0.08%	105566.37	0.00	0.00%
Distributor 3 Cost	53812.31	811.97	0.77%	65377.69	3599.62	2.82%
Distributor 3 Profit	49789.14	758.04	0.79%	40188.68	3550.21	4.70%
Service Level (type 1) for Product 1	77.71%	1.40%	0.91%	78.28%	1.02%	0.67%
Service Level (type 1) for Product 2	76.78%	1.52%	1.10%	78.52%	1.14%	0.76%
Service Level (type 1) for Product 3	78.85%	1.70%	1.09%	77.03%	1.47%	1.00%
Service Level (type 2) for Product 1	76.91%	0.03%	0.02%	77.52%	0.03%	0.02%
Service Level (type 2) for Product 2	76.80%	0.01%	0.01%	77.13%	0.04%	0.02%
Service Level (type 2) for Product 3	76.25%	0.03%	0.02%	77.21%	0.02%	0.02%
Total Revenue	764557.81	2321.82	0.16%	760121.66	2225.40	0.15%
Total Cost	526868.30	11309.30	1.12%	492581.53	11226.65	1.22%
Total Profit	237689.51	12682.17	2.85%	267540.13	13070.35	2.67%

Case #33

Scenario 3	Case Type 10					
	RMI			VMI		
	Value	Standard Deviation	% Relative Error	Value	Standard Deviation	% Relative Error
Retailer Revenue	443617.47	3005.14	0.38%	443776.13	1505.89	0.19%
Retailer Cost	366946.85	11143.39	1.68%	315022.07	460.81	0.08%
Retailer Profit	76670.61	13602.73	9.83%	128754.07	1460.41	0.63%
Distributor 1 Revenue	103364.10	221.93	0.12%	104580.00	0.00	0.00%
Distributor 1 Cost	51755.60	1360.42	1.46%	57575.20	2705.44	2.60%
Distributor 1 Profit	51608.50	1315.52	1.41%	47004.80	2705.44	3.19%
Distributor 2 Revenue	103099.92	252.44	0.14%	104580.00	0.00	0.00%
Distributor 2 Cost	53452.06	2273.21	2.36%	62118.27	5307.62	4.73%
Distributor 2 Profit	49647.86	2185.83	2.44%	42461.73	5307.62	6.92%
Distributor 3 Revenue	102921.00	337.47	0.18%	104580.00	0.00	0.00%
Distributor 3 Cost	54798.50	1823.45	1.84%	63989.60	5190.62	4.49%
Distributor 3 Profit	48122.50	1672.97	1.93%	40590.40	5190.62	7.08%
Service Level (type 1) for Product 1	73.88%	3.21%	2.41%	72.75%	2.66%	2.02%
Service Level (type 1) for Product 2	74.51%	2.28%	1.69%	73.50%	2.56%	1.93%
Service Level (type 1) for Product 3	74.29%	2.19%	1.63%	74.14%	2.05%	1.53%
Service Level (type 2) for Product 1	76.88%	0.04%	0.03%	76.80%	0.04%	0.03%
Service Level (type 2) for Product 2	76.71%	0.02%	0.02%	76.88%	0.04%	0.03%
Service Level (type 2) for Product 3	76.64%	0.03%	0.02%	76.63%	0.03%	0.02%
Total Revenue	753002.49	3277.22	0.24%	757516.13	1505.89	0.11%
Total Cost	526953.01	11347.61	1.19%	498705.13	11219.34	1.25%
Total Profit	226049.47	13760.98	3.37%	258811.00	11962.61	2.56%

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