A Simulation Investigation on Impacts of Transportation Disruption for Vendor Managed Inventory Model and Traditional Inventory System

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Abstract: Nowadays, Supply Chain Management (SCM) becomes an important issue and involves managing integrated information about product flow, improving efficiencies. One of the important issues of SC is implementing close coordination and relationship among its members. This paper considers two different approach of inventory management which called Traditional Inventory Management (TIM) and Vendor Managed Inventory (VMI) and propose a simulation method to observe the impacts on system efficiency and average inventory level while a transportation disruption situation happened through supply chain comparing with a normal situation. The stimulated members of SC are such as Distributor and Manufacturer. The model supposed that Manufacturer as a producer member has two separate warehouses which called here Raw Material and Product inventories. The models were simulated for 34 months (12,000 hours) by five times replications. Likewise, a disruption is supposed about two months thorough transportation on supply chains. The results show that the reduction of efficiency for TIM model was 17% while for VMI it was obtained by 12% when the disruption occurred in SC. In this context, it can be concluded that VMI is less sensitive when disruption happened and TIM is more vulnerable rather than VMI. The reason belong to this result is due to a great information sharing through all supply chain members. Furthermore, the fluctuation of average inventory level occurred much more on TIM rather than VMI. In proposed VMI model, manufacturer inventory (Product) experienced the largest fluctuation in its average inventory level and it is the most sensitive partner while disruption occurred. However, distributor member in TIM experienced the largest fluctuation in its average inventory level, therefore, it is the most sensitive member towards transportation disruption.

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1. Introduction

Supply chain (SC) is described as a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed forward flow of materials and the feedback flow of information (Stevens 1989). During these years Supply Chain Management (SCM) becomes an important issue. SCM involves managing integrated information about product flow, improving customer satisfaction and reducing cost of inventories (Parmar 2007). Although storing inventory has lot of advantages for SC member, it is important to be careful about the level of inventory which must be stocked. Nowadays, managers attempt to store the stock down as long as they are able to meet their customer satisfaction. Reducing inventory level without affecting the availability of product is one of the essential goals in SCM (Chopra and Meindl 2001). In addition, another important issue in SC is implementing close coordination and relationship among its members. For this mean information sharing is employed which leads to have successful SC. Information sharing increases the chain's visibility and is used for coordinating the material flow (Soroor, Tarokh, and Shemshadi 2009). Based on the research of Cachon and Fisher (2000), the benefits of information sharing along the SC become obvious. Yao and Dresner (2007) concluded that information sharing in SC can reduce safety stock, thereby the average inventory level is reduced.

Moreover, As Centre for Research on the Epidemiology of Disasters observed the disasters have increased exponentially worldwide over the past decades, therefore, SC becomes more vulnerable to disruption (Parmer, 2007). Unexpected disruption in

SC makes negative effects on chain's performance, hence, considering the probability of risk in chain become important. The terrorist attacks on 11 September 2001, the SARS epidemic in South-East Asia, the recent H1N1 epidemic that plagued the whole world and the most current Haiti earthquake are examples of risks which are faced by SC. By considering these happening during previous decade a lot of attentions goes to SC disruption and its management.

By considering the importance of inventory management policies, information sharing and disruption in SC, this research investigates on these issues. According to above, this research has attempted to propose two SC model based on combination of information sharing and inventory management policies. It should not be forgotten to say that the proposed model is strategized by "Make to Order" policy. The models are called Traditional Inventory Model (TIM) and Vendor Managed Inventory (VMI). The VMI is supposed based on information sharing and maintaining the inventory on a min level. However, the policy of inventory in traditional model is considered on max inventory without any information sharing tools. Then simulation modeling is employed in order to evaluate impacts of transportation disruption on system efficiency and average inventory level as defined KPIs of this paper. The aim of this investigation is to determine the vulnerable model and member in given SC for having a proactive planning.

2. Disruption in Supply Chain

In recent years, it can be seen that SCs are prone to disruptions. These disruptions occurred because of natural disasters like earthquakes or tsunamis or it can be because of human activities like the occurrence of wars and embargos. The high regard that manager and firms are paying to disruption is triggered by the frequency and intensity of catastrophes, disasters and crises that have increased in the global scale (Coleman, 2006, Helferich and Cook, 2002). As Figure 1 shows both natural and man- made disasters have increased exponentially worldwide during the past decades (Centre for Research on the Epidemiology of Disasters, 2004). Therefore, SCs become more vulnerable to disruption during these years (Christopher and Peck 2004).

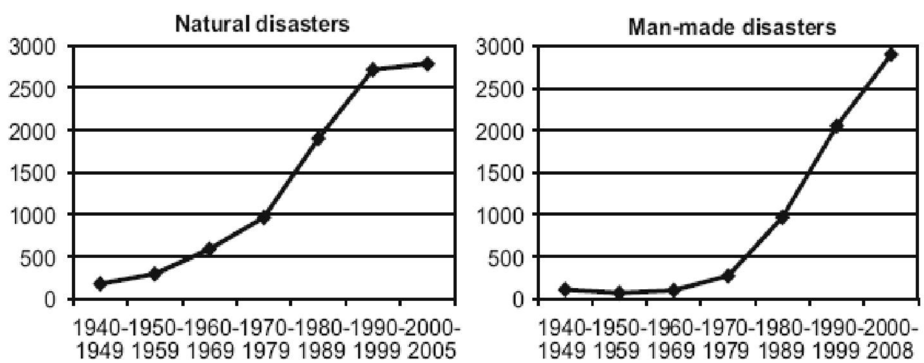


Figure 1.Distribution of natural and man-made over time
(Centre for Research on the Epidemiology of Disasters, 2004)

G. Zsidisin (2007) reportde that unnatural disasters such as war, terrorism, sabotage and natural disasters like tsunamis, floods, earthquakes and health disasters which contains SARS, avian flu and SC infrastructure such as inbound and outbound shipping, manufacturing facilities and overall logistic system are the major sources of disruption in SC. Industries are affected differently by SC disruption (Hendrik and Singhal 2005). The automotive industry has the highest vulnerability towards the disruptions among the industries ,(Hannon 2008; Wagner and Neshat 2009). For instance, the disruption which happened in the chain of Robert Bosh GmbH, the world largest auto-parts supplier in January 2005 leads to negative effects on financial statues and brand image of Bosch (Wagner and Neshat 2009).

Based on benchmarking which was done by Aberdeen group (2006) 80% of the firms reported that they experienced disruption during the previous months. They added this disruption negatively impacted on their sale, earning, customer satisfaction and brand of them. Although, 62% of the supply chains expect disruption and risk in near future, just around 49% of them try to have risk management plan for mitigating the negative effects of disruption (Aberdeen Group, 2007) . The lack of strategic planning and action gap towards disruption are the main problem of companies in period of disruption, therefore, having proactive planning and preview towards these issues are essential for facing to disruption (Connaughton, 2007, Parmar 2007). Although there are various researches that investigated the types and impact of disruption in a SC, there has been less attention on transportation disruption which can quickly cripple the entire SC and also there exists evidence of several shortcomings in this area (Wilson, 2007, Kleindorfer and Sadd, 2005). Transportation disruption leads to making delay or stoppage in goods flow and also goods production. Actually it arises when the material flow is faced problem between two echelons in supply chain (Chopra and Sodhi 2004). For instance the terrorist attack to Pentagon in 2001 lead to stoppage of many assembly lines of Ford just because of delayed at Canadian and Mexican border which had happened following of attack (Sheffi, 2001). Table 1 has summarized literature review of related issues in this research.

Table1. Summary of literature review

Authors	year	Scope of research
Kleinder and Sadd	2005	Disruption in SC has not widely studied, it needs more investigation.
Martha C. Wilson	2007	In order to mitigate the negative effects of SC disruption, it is important to have early investigation on this issue. Also he added that transportation disruption as subset of disruption resources received less attention than other disruption in SC. He investigates on transportation disruption in push SC and also the defined transportation disruption was between each two echelons separately.
Christopher and Lee/Lee and Walfe/Rice and Caniato/Staar, Newfrock, and Delurey/Sheffi and Rice/Tang	2001/2003/2003/2 003/2005/2006.	They Have different recommendation for successful uncertainty managing uncertainty managing
Data and Christopher	2010	He showed the value of information sharing and coordination between the chain's members in order to managing the uncertainty in SC by focusing on push system or "make to stock". He illustrates that there is need to investigate on combination of recommendation for having a successful uncertainty managing They Have different recommendation for successful
Li and Wang	2007	He explained that previous researches did not find an effective mechanism for encountering the uncertainty and disruption.
Parmer	2007	The action gap towards the disruption is the greatest weakness of supply chain. The early warning system is necessary for mitigating the SC disruption.
Connaughton	2007	Having proactive planning and preview to disruption and effects of that are essential
Giunipero and Eltantawy	2004	The research which has done on the area of transportation disruption is so general and cannot cover the strategy for mitigating the effects of that.
Chen et al. /Lee / Lee, Padmanabhan, and Whang / Lee and Billington /Levy / Sterman and John/ Cachon/ Zsidisin	2000/2002/1997/1992/1995/1989/2004/2003	They show importance role of information sharing, electronic data interchange, collaboration planning, replenishment, for mitigating the negative effects of disruption in SC.

He illustrate that there are lots of researches which have been published on coordination among chain but there are little works that explicitly take uncertainty into account.

Tyan, Wang and Du 2003 As “Make to Order” bring more advantages for firms rather than “make to stock”, therefore, most of the firms are interested to replace it.

Ting and Khoo 2007 He explained that there are lots of researches which have been done on the area of push system of SC but there is just few on pull strategy.

Gunasekaran and Nagai	2005	“Make To Order” strategy becomes popular after its successful implementation by Dell and Compaq in Pc industry, it must still implement in the other high value industries like automobile that need to be flexible to their customers need. He explained that there is need to investigate more on new strategy of “Make to Order”, especially in designing and controlling “Make to Order” supply chain.

Gonkar and Viswanadham/ Kouvelis, Chambers and Wang / Hendricks and Singhal 2003/2006/ 2005 Investigated on safety mechanism for protecting the SC and reducing negative and costly effects of disruption is essential.

2005 Studied disruption stage and provide recommendations for having flexible SC.

Yusef et al. 2004 Found that information integration and high degree of coordination between the chain’s members are useful factors for agility of supply chain.

2008 Developed a framework for global supply chain risk management.

Christopher and Lee/ Blackhurst et al.
2004/2005 Having more visibility and capacity management are helpful in managing and reducing the chain’s risk.

Tang/ Kouvelis, Chambers and Wang
2006/2006 There is need to have more investigation on supply chain risk management issue.

Kleindorfer and Saad / Christopher and Lee/ Lee and Walfe /Rice and Caniato
/Staar, Newfrock, and Delurey/ Sheffi and Rice / Tang
2005/2001/2003/2003/
2003/2005/2006
Provided different recommendation for successful uncertainty managing.

Data and Christopher	2010	There is need to have more investigation on the effects of different practices which have been recommended by previous researcher and assess the system performance under uncertainty and disruption for combination of these recommended practices.

Based on table1, importances of this research are revealed as:

First of all there are limited researches in the area of determining the vulnerability of supply chains which have different structures and also identifying the sensitive members to disruption in a given supply chain (Wilson, 2007, Kleindorfer and Sadd 2005) . Secondly previous researches investigated transportation disruption between two echelons in a supply chain (Wilson, 2007) and not the whole supply chain as will be the case when disasters such as big floods or earthquakes occur. Thirdly, most of the work on supply chain disruption has focused on "Make to Stock" or push supply chains as opposed to pull supply chains which are getting more prevalent now. Also, Datta and Christopher (2010) focused on "Make to Stock" strategy and proposed "Make to Order" or pull SC as future research to evaluate the combined effects of information sharing and coordination among chain's members for managing uncertainty.

3. Material and Method

As mentioned previously, this paper has investigated on two different points of views toward SC for information sharing and inventory managing. The first one is Traditional Inventory Model (TIM) and the second one is Vendor Managed Inventory (VMI). The first model (TIM) has no information sharing along its chain and it is based on inventory management in pull based SC but the second model (VMI) contains information sharing among the whole members of pull based SC and also it contains close co-operation for its inventory managing. Therefore this investigation firstly, proposes two models, and then based on importance of transportation disruption, the models were simulated for 12,000 hours in two statuses which are normal situation and disrupted situation. The aim of this investigation is to analyze the impact of transportation disruption on both proposed models and to identify which model has higher performance under transportation disruption situation and also to identify the sensitive member of SC. For this mean system efficiency and average inventor level are defined as two KPIs of this research.

To have a better overview from the proposed SC for this research, authors depicted the chins, member and the flow or supply on the material and the product in Figure 2. In the following sections the TIM and VMI will be explained by detail.

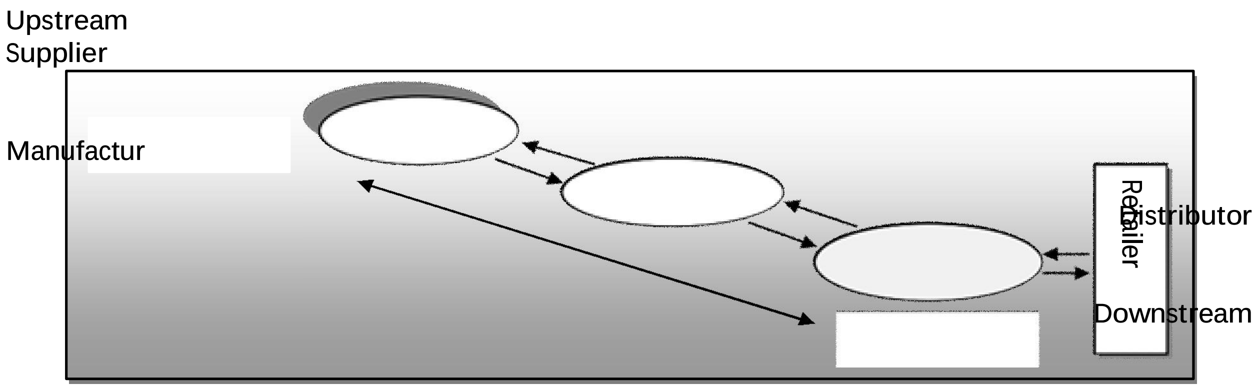


Figure2. Proposed supply chain model for this research

Ø **Proposed Traditional Inventory Model (TIM) for Supply Chain:**

There is no information sharing among the chain's member in this model, therefore, upstream members use replenishment information from immediate downstream member to respond incoming orders. The information directly is sent by the downstream member to upstream partner of chain based on the coming orders. Demand from the downstream partner leads to shipments of goods and pull the products from the upstream member in supply chain. In this model which will be explained by details further, each member of chain is responsible for its inventory managing and replenishing. Based on "Make to Order" strategy which is employed in TIM, the production is not started in the system until the retailer's order comes to the system, when the retailer's order comes to the system, the system will start its production based on the retailer's requirement, therefore, the retailer will be satisfied because they receive the product with the exact specification which they defined. On the other hand, in this model, the material flow is triggered when the downstream member pulls the material from its upstream partner. Furthermore, in TIM, the max inventory replenishment is proposed for each member by evaluating its own inventory level. Based on this inventory policy, while remained inventory at each echelon of chain meets Re-Order Point (ROP) level, the manager place order to fulfill the warehouse and reach the level of inventory to the maximum initial inventory.

As Figure 3 shows, the automobile retailer's orders come to the system and distributor receives the orders (step1, 2). The orders are checked by distributor either they have sufficient inventory or not (step3). If enough inventories be available, they ship to the retailer. Simultaneously, they update their inventory level and also check the remained inventory level with Re-order Point (ROP) which is defined by Economic Order Quantity (EOQ) model (step7, 8, 9, 10, 11). If remained inventory be more than ROP, there is no need for ordering to manufacture, otherwise order must be sent to manufacturer (step12, 13). The quantity of this order is equal to the difference of current distributor inventory and the maximum initial level of inventory in distributor. The other statues may be happened if there is no sufficient inventory at distributor hand, therefore, retailer decides whether wait for automobile or leave the system. If retailer decides to wait, orders are sent to manufacturer (step 4, 5, 6). After receiving orders by manufacture, the inventory level of automobile is checked whether they have enough automobile for sending to distributor or no (step14). If they are able to meet the distributor's order, the automobile is loaded and shipped to distributor, then manufacturer inventory level (product) is updated (step15, 16, 17, 18, 19, 20, 21). Otherwise, if manufacturer does not have sufficient inventories, based on the pull based system logic, the production want to be started but before that, the order quantity must be checked with Economic Production Quantity (step22).

Beside the inventory managing definition, Economic Production Quantity (EPQ) is an important issue in producing company. Economic Production Quantity is defined for optimizing cost and number of production. On the other hand, the function of this model is to balance the inventory holding cost and the ordering cost. Economic Production Quantity is defined based on the strategy, long term planning and demand of company. When the order quantity be less than EPQ, production is not started, it will wait until the other orders come and production quantity becomes equal or more than EPQ. If manufacturer concludes that the number of incoming order is economic for production, the number of production is calculated and then checked by manufacturer inventory (Raw material) (step 23, 24, 25). By sufficient raw materials, manufacturer start its production, otherwise it must wait for replenishing the raw materials by supplier (step 26, 36). After finishing production process, the inventory level of manufacturer (product) is updated (step 27). According to quantity of incoming orders, the produced automobile is sent to distributor. By each deduction of raw material at manufacturer level, remained inventory is checked by ROP for clarifying whether it needs to place order or no (step 28, 29). If manufacturer face shortage of raw material, the order is sent to supplier and supplier respond to manufacturer's requirement (step 30, 31, 32, 33, 34).

Step1
Retailer Arrival

Step2

Receiving the orders by Distributor

Yes

Step4

Retailer wait or leave the system?

Step3

NO

Automobile
available is enough?

Yes

Step7

Update Distributor Inventory

NO

Step5

Retailer leave the system

Step13

Do Nothing

Step 11

NO

Is Remained inventory
≤ ROP?

Step 8

Load
Automobile

Step 6

End

Yes

Step 12

Fill the Gap

Step 9

Transport to
Retailer

Step 10
1
End

1

Step 39

Do nothing

Yes

Step 29

Is Manufacturer inventory(Raw material)≥ ROP

Step22

No

Is Order≥ Economic
Quantity of production?

Step 14

No

Is Manufacturer
Inventory(Product)≥

Order?

Yes

Step 15

Update Manufacturer Inventory(Product)

No
Yes

Step 30

Order to supplier
Step 23

Calculate lead time

Step 16

Load the
Automobiles

Step 31

Supplier receive the orders and batch the material

Step 32

Update the raw material

Step 33

Transport to
Manufacturer

Step 36

Order to supplier

Step 37

Supplier receive the orders and batch the material

Step 38

Update the
Raw material

Step 24

Calculate No of Production

Step 25

No

Is Raw material ≥No of production?

Yes

Step 26

Start producing

Step17

Transport to
Distributor

Step 18

Receiving by
Distributor

Step 19

Unload the
Automobiles

Step 20

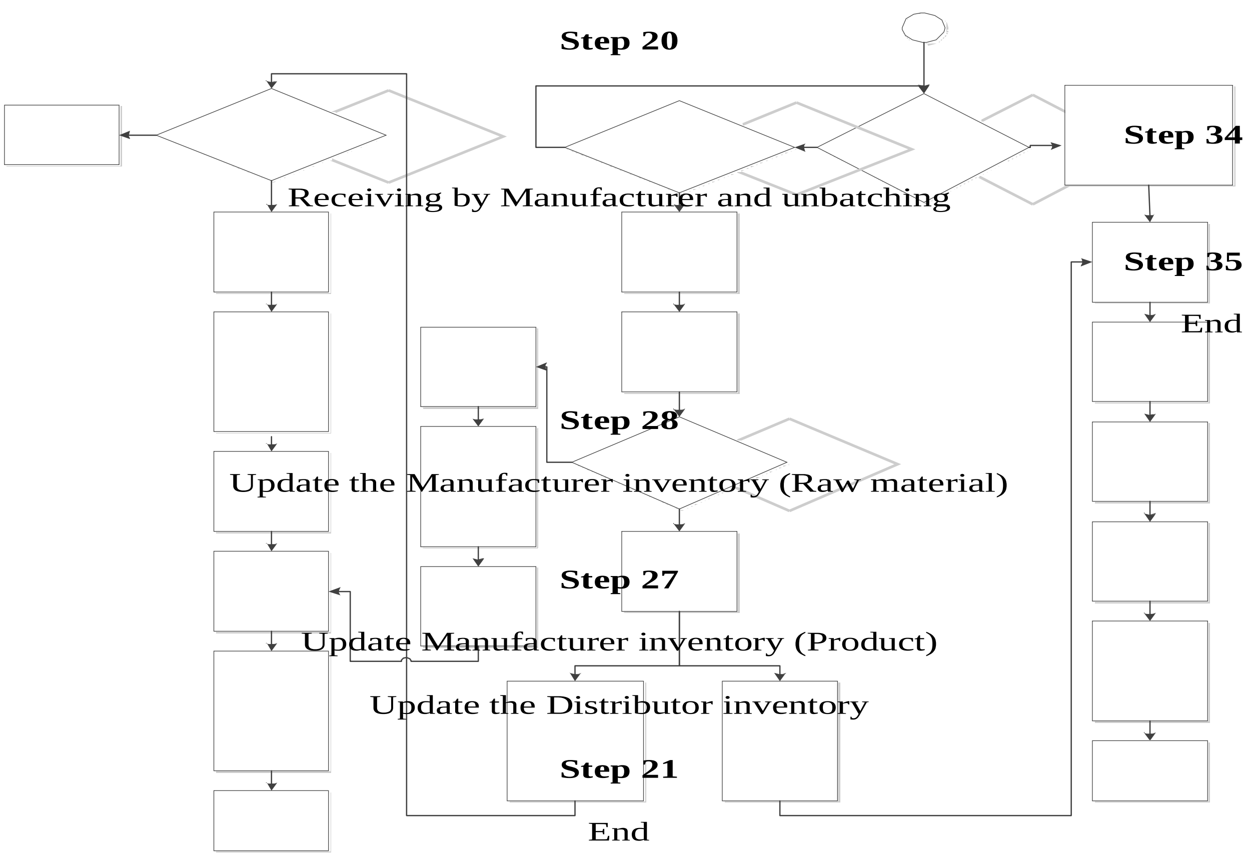


Figure3. Proposed Traditional Inventory Conceptual Model for Supply Chain

Ø **Proposed Vendor Managed Inventory (VMI) Model for Supply Chain**

In proposed VMI model of this investigation the information is shared between all members of chain in contrast with previous models which shares information just between two members of chain. The information is shared via the EDI among the whole members of chain. Based on the shared information, each member is responsible for managing and replenishing of its downstream partner's inventory. On the other hand, the main feature of VMI is inventory managing of customer by its vendor, in the proposed VMI model, this inventory managing responsibility which is done by vendor has been defined during the whole chain and between the whole members of SC. In contrast, the previous VMI models just defined this responsibility between two echelons of SC. Therefore, this proposed VMI model contains the information sharing and also the inventory managing by vendor along the whole chain and between the whole members. Furthermore, to design the proposed VMI model of this research, maintaining ROP inventory level was employed for its inventory managing policy. This strategy is used by each upstream member of SC for deciding whether needs to replenish inventory, fulfill the gap and increase the inventory to the ROP level and try to keep it at that level.

Figure 4 depicts, in VMI scenario, retailer's order come to the chain and is checked by distributor (step1, 2). Simultaneously, they share retailer's demand data with manufacturer via the EDI (step3). The inventory level of distributor may be enough for responding to retailer's order or may not (step4). If distributor does not have enough automobile inventories, retailer decides whether wait or leave the system (step5). If the available inventory is sufficient, distributor ship the automobiles to retailers and then, inventory updating is done (step 8, 9, 10, 11). Also, they use EDI to inform manufacturer the current level of their inventory (step12).

Based on the information which has shared by EDI, manufacturer control the distributor inventory, decide when and what quantity is needed to send automobile for distributor (step13). The main difference between the proposed traditional and VMI model is on information sharing which exists in VMI and leads to better collaboration between the chain's members. Moreover, inventory managing is done by upstream member of chain for downstream in VMI. Based on mentioned differences between the proposed VMI and traditional model, after the automobile shipment to retailer, manufacturer control the inventory level of distributor (step13). This control is done for preventing the shortage of automobile in distributor level. If manufacturer perceives that inventory level of distributor fall down the Reorder Point (ROP), they decide to provide and send automobile to distributor (step13, 15). Manufacturer checks their own inventories, if sufficient automobile be available, they send to distributor (step16, 17). Otherwise they decide to produce automobile based on distributor's requirement. If the number of order be more than , then lead time and quantity of production are defined (step24, 25, 26). In this part, manufacturer transfer the production planning to supplier via EDI (step27). As mentioned above, one of the most important attribute of proposed VMI is responsibility of upstream members towards downstream members for inventory managing. For this reason, at the same time supplier check raw material inventory level of manufacturer based on the production planning which is shared by manufacturer via the EDI, and then make decision when and what quantity of raw material they must send to manufacturer (step28). If supplier observations show that the inventory level of raw material in manufacturer is sufficient for production, manufacturer be aware of this and start their production (step32). Otherwise, supplier prepares the quantity of raw material which is needed by manufacturer, then ship it to them (step29, 30, 31). The inventory level of both raw material and finished product are updated after each deduction or increment (step30, 34). Also, after each deduction from raw material, manufacturer use EDI to share the inventory level of raw material with the supplier (step35). Supplier uses this shared information for checking the inventory level with ROP and decides whether it is needed to send raw material to manufacturer or no (step36).

To sum up, in the proposed VMI structure, the downstream member of chain allows the upstream member to be aware of demand information and inventory level via the EDI. Upstream member uses this information for their planning. In proposed VMI model, maintaining ROP inventory level was employed when the inventory fall down the re-order point. The order quantity in proposed VMI model is calculated by downstream requirement plus ROP inventory level.

Figure 4 shows the proposed VMI model for SC as follows:

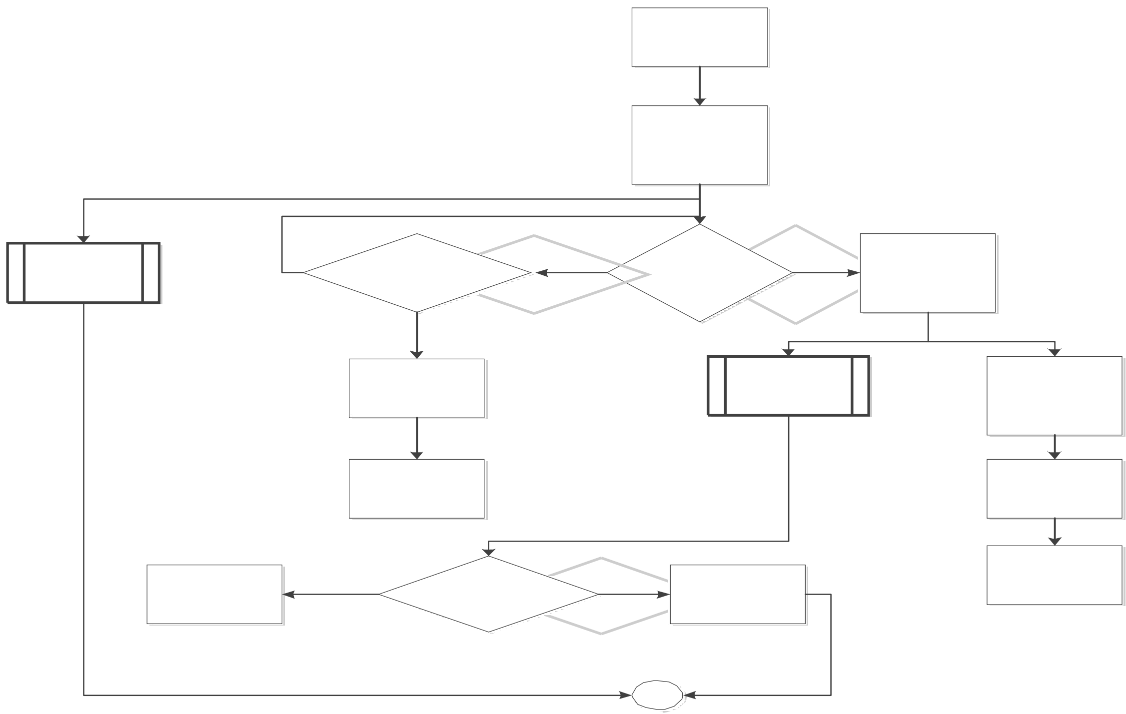


Figure4. Proposed Vendor Managed Inventory Conceptual Model for Supply Chain

Step1

Retailer Arrival

Step2

Receiving the orders by Distributor

Step 3

EDI(1) to

Manufacturer

Yes

Step 5

Retailer wait or leave the system?

Step 4

No

Automobile available is enough?

Yes

Step 8

Update Distributor Inventory

No

Step 6

Retailer leave the system

Step 12

EDI(2) to Manufacturer

Step 9

Load Automobile

Step 7

End

Step 10

Transport to Retailer

Step14

Do Nothing

Step 13

No

Is Remained inventory ≤ ROP?

Yes

Step 15

Try to fill the gap

Step11

End

1

1

Step24

No

Is Order≥ Economic Quantity of production?

Yes

Step 25

Calculate lead time

Step 16

No

Is Manufacturer
Inventory(Product)≥
Order?

Yes

Step 17

Update Manufacturer Inventory(Product)

Step 18

Load the
Automobiles

Step 26

of Production

Step19

Transport to
Distributor

Step27
EDI(1) to
Supplier

Step 20

Receiving by
Distributor

Step 29

No

atching by
Supplier

Step 28

Is Raw material ≥

No of production?

Yes

Step 32

Start producing

Step 21

Unload the
Automobiles

Step 30

Update the Raw material inventory

Step31

Transport to
Manufacturer

Step 34

Update the Manufacturer inventory (Raw material)

Step35

EDI(2) to Supplier

Step 33

Update Manufacturer inventory (Product)

Step 22

Update the Distributor inventory

Step 23

End

Step 37

Do nothing

Step 36

Yes No

Is Manufacturer
inventory(Raw material)≥
ROP

Step 38

Batching by
Supplier

Step 39

Transport to
Manufacturer

Step 40

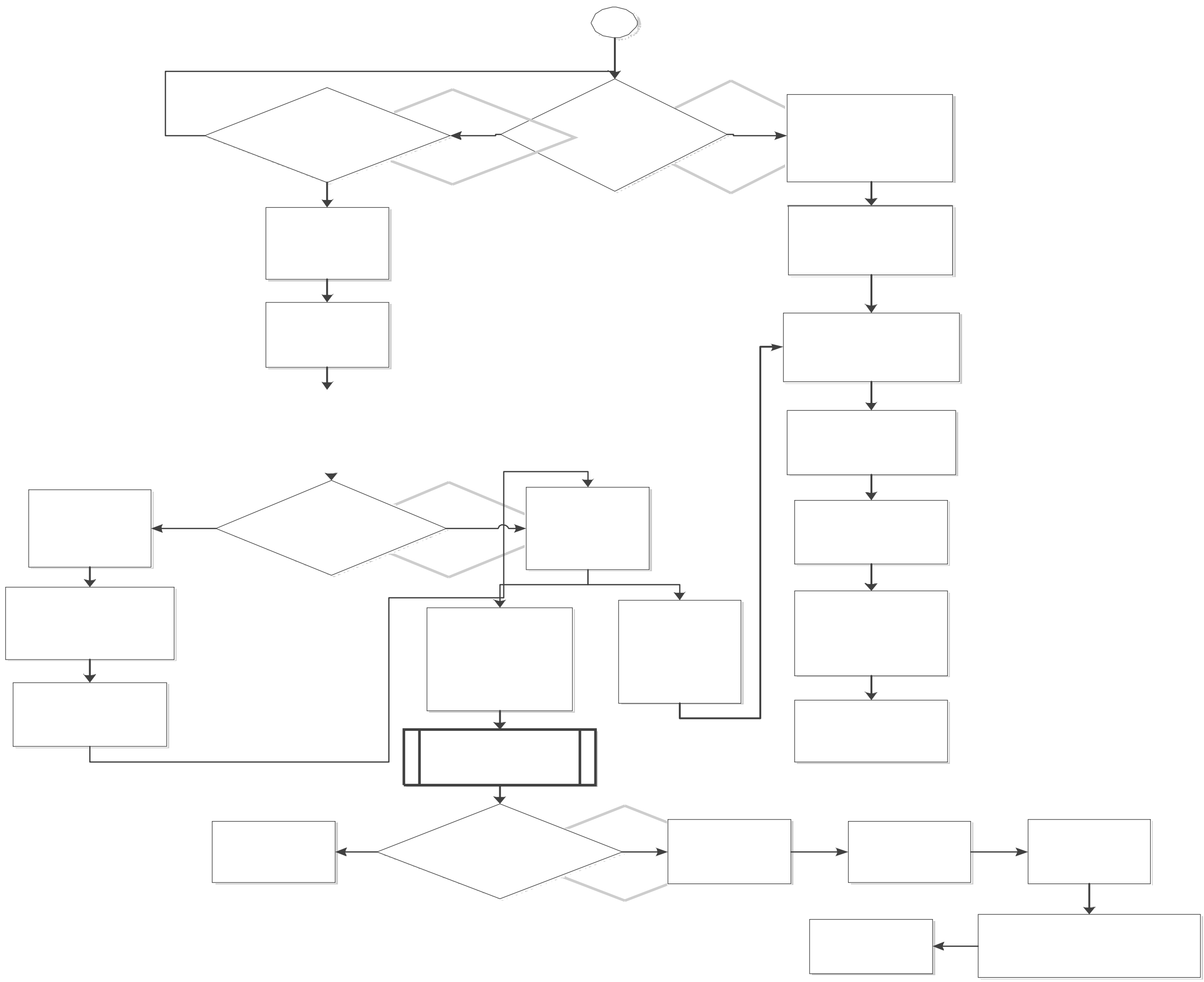
Update the raw material

Step 42

End

Step 41

Receiving by Manufacturer and unbatching



4. Result and Discussion

To simulate the model for this investigation, Arena software (version 13) has been applied as the powerful simulation software for simulation researches. Both proposed models are simulated five times over a time period of 12,000 hours by the warm up period of 500 hours. Since this research investigates on effects of transportation disruption, hence, each model is run under two conditions; normal situation and transportation disrupted situation. In the normal situation, the transportation time between the members is assumed 16 hours but in disrupted situation, when the problem happens in the system, it leads to delay in transportation along the chain, therefore, the transportation time increases to 64 hours. The disruption must occur after the warm-up period in simulation running for ensuring that the system's behavior is steady and the obtained results are accurate (Wilson, 2007). Therefore, the disruption happens in the 1760th hour in the system and takes 700 hour, then the system will work normally again. As this paper investigates on two KPIs which are system efficiency and average inventory level, so that the Arena records the defined KPIs and reports as follows:

- **System Efficiency Percentage**

The system efficiency of proposed models depicts in Table 2. The results illustrate that the efficiency of TIM is 79% for normal situation and when transportation disruption happens among the whole members of chain it decreases to 65%.

Similarly, the efficiency of VMI has decreased from 84% to 74% when the disruption occurs in the system. Therefore, the less reduction in VMI efficiency rather than TIM when disruption happens shows that, VMI model is less sensitive and vulnerable to disruption. On the other hand, TIM is more vulnerable to transportation disruption rather than VMI, because by the information sharing which exists in VMI model, the unplanned disruption which may occur in SC becomes easier to manage in comparison to TIM.

Table2. Comparison of system efficiency of VMI and TIM

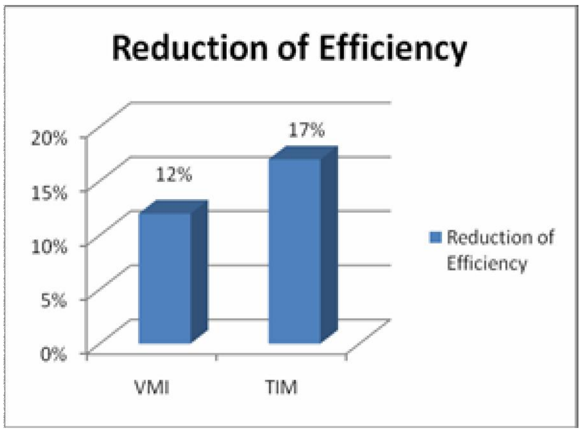
Normal situation

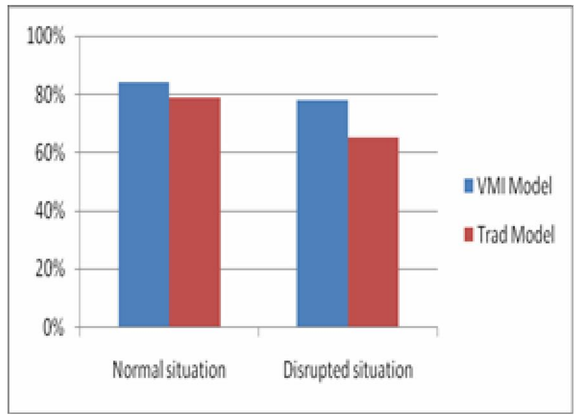
Disrupted situation

Figure6. Reduction of Efficiency on VMI & TIM

VMI 84% 74% TIM 79% 65%

Also, Figure 5 shows that proposed VMI model has greater system efficiency rather than TIM in both normal and disrupted situation, therefore, it has better performance rather than TIM, and also it is less sensitive to disruption.





- **Average Inventory Level in VMI and TIM**

Another KPI of this research is Inventory level. Table 3 shows the inventory level of each member in SC under two identified situations. The inventory levels are obtained from simulation report after five times replications in normal status and disrupted status.

Table3. VMI Simulation Results

Case Manufacturer Inventory Level (Raw Material)

Manufacturer Inventory Level (Product)

Distributor Inventory Level

Normal situation

Disrupted

2093 1636 542

1993 1532 526

situation

Figure5.Comparison of system efficiency between VMI & TIM

According to Figure 6, in VMI model, the reduction of efficiency while destruction occurred is about 12 % while it is measured 17 % for TIM model. The lower fluctuation in VMI model reveals that VMI is less sensitive rather than TIM model.

Since transportation disruption simultaneously happened in the system between supplier - manufacturer and also manufacturer - distributor, therefore, the level of inventory decreases for two warehouses after disruption. Table 3 represents that the disruption on VMI did not effects much more on the average inventory level of members because, with the information sharing and good co-operation which exists in VMI, the members can mitigate the negative effects of disruption on their inventory level. On the other hand, by information sharing in VMI model, the SC visibility is increased and leads to better inventory managing and planning. In addition, Table 3 shows that in proposed VMI model, the manufacturer inventory (Product) experienced the largest fluctuation in its average inventory level and is the most sensitive partner to disruption. Also, in TIM, s shown in Table 4, distributor experienced the largest fluctuation in its average inventory level and is the most sensitive member to disruption.

In addition, the simulation results for inventory level of TIM's members under two situations of normal and disrupted are shown as Table 4.

Table4. TIM Simulation Results decreases from 2119 to 1980 units, and also the average inventory of manufacturer (Raw material) decreases from 2866 to 2861 units, therefore, the efficiency of system when disruption happens should be decreased accordingly. Indeed, when the disruption happened, the flow of goods face with delay, therefore, it leads to make the problem of lacking inventory for the members. Therefore, in disrupted period, the inventory level of them comes down and after overcome to the disruption the inventory will go up again, therefore, it leads to more fluctuation in average inventory level which is the consequence of information sharing lack.

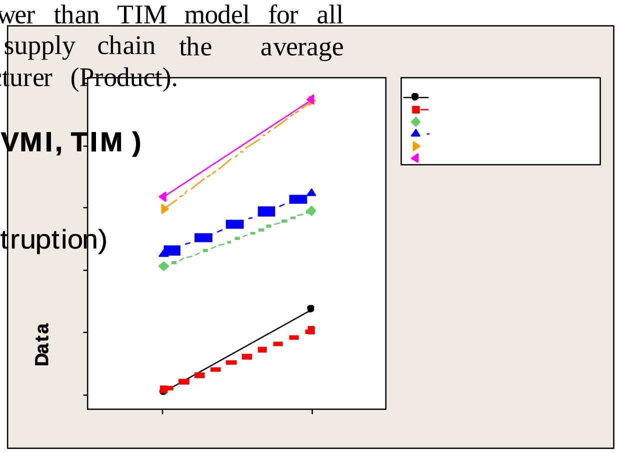
Case Manufacturer Inventory Level (Raw Material)
Manufacturer Inventory Level (Product) Distributor Inventory Level

However, the result reveals that the average inventory of raw material belongs to manufacturer in VMI has not decreased less than TIM. It is due to Normal situation Disrupted situation

2866	2119	1020
2861	1980	1193

Based on Table 4 when disruption occurs, lack of information sharing with Tier 2 supplier.

Figure7 depicts the comparison between VMI and TIM model for all member average inventories. It can be demonstrated that the average of inventories are lower than TIM model for all warehouses through supply chain the average inventory of manufacturer (Product).



3000
Line Plot of Mean(VMI, TIM)

C1
Disctibutor Inv. (Distruption)
2500
2000

1500
1000
500
Disctibutor Inv. (Normal)
Manufacturer Inv. Product (Distruption)
Manufacturer Inv. Product (Normal)
Manufacturer Inv. Raw (Distruption)
Manufacturer Inv. Raw (Normal) VMI, TIM

Figure7.Glimpse comparisons between VMI & TIM for all members

Figure 8 shows that that average fluctuation for VMI model is less than TIM model when comparison has been taken in account on a average of all inventories warehouses. It can demonstrate that for a whole comparison on all members' inventory level, the reduction of inventory for VMI is 4.66% while for TIM was resulted by 7.86 %.

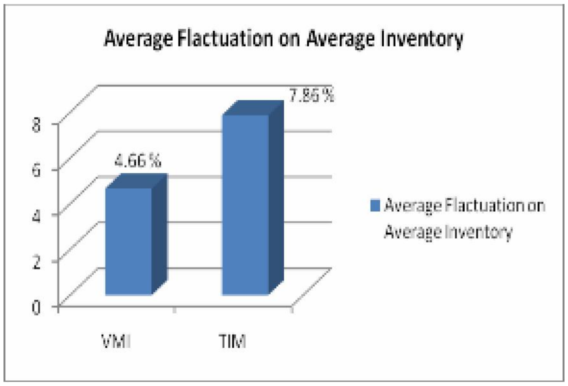


Figure.8: average Fluctuation on Average Inventory for whole chain

5. Conclusion

In transportation disrupted situation, there are delays in material and product flow among the chains. It leads to reduction in responded orders and system efficiency for both models but the simulation results indicate that changes in efficiency and inventory level are less for proposed VMI model rather than TIM. Moreover, although both models feel the impacts of transportation disruption on their efficiency and inventory level, the less reduction in system efficiency and inventory level in proposed VMI model in comparison to TIM under transportation disrupted situation indicate that VMI model is less sensitive and vulnerable. Therefore, TIM is more sensitive to transportation disruption. Also, Manufacturer inventory (Product) is most sensitive partner in proposed VMI model and Distributor is most sensitive partner in TIM as they have more fluctuation in their inventory. According to the results, the sensitivity of VMI when disruption occurred is by 12 % while for TIM was obtained by 17 %. It can be concluded that proposed VMI is less vulnerable when disruption occurred.

The differences that make VMI model more efficient than TIM are information sharing and vendor inventory managing system which exists in VMI model, also, coordination among players is a key to success. As far as decision makers are looking for decision support, the results of this investigation can be employed by decision makers for an effective decision. It may help them to decide about implementing VMI in their chains to bring higher productivity into chain and even less damage and vulnerability in disrupted situation.

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References

1. Blackhurst J, Craighead C, Elkins D, Handfield An Empirically Derived Agenda of Critical Research Issues In Managing Supply Chain Disruptions . International Journal of Production Research 2005; 43: 4067-4081.
2. Cachon G.P, The Allocation of Inventory Risk in A Supply Chain: Push, Pull, and Advance Purchase Discount Contracts. Management Science 2004; 2: 222-238.
3. Cachon G.P, Fisher M. Supply Chain Inventory Management And The Value of Shared Information. Management Science 2000; 46:1032-1048.
4. 4. Chen F, Drezner Z, Ryan J.K, Simchi D. Quantifying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead times, And Information. Management Science 2000; 3: 436-443.
5. 5. Chopra S, Meindl P. Supply Chain Management: Stratagy, Planning and Operation. Englewood Cliffs. 2001.
6. Chopra S, Sodhi M.S. Managing Risk To Avoid Supply Chain Breakdown. MIT Sloan Management Review 2004; 46: 53-61.
7. Christopher M, Lee H. Supply Chain Confidence–The key to Effective Supply Chains Through Improved Visibility and Reliability. Vastera Corporation White Paper, Cranfield and Standford. 2001.
8. Christopher M, Lee H.L. Mitigating Supply Chain Risk Through Improved Confidence. International Journal of Physical Distribution & Logistics Management 2004; 34: 388-396.
9. Christopher M, Peck H. The Five Principle of Supply Chain Resilience. Logistics Europe 2004; 12: 16-21.
10. Coleman L. Frequency of Man-made Disasters in The 20th Century. Journal of Contingencies And Crisis Management 2006; 3-11.
11. Connaughton P. Best Practices: Successfully Managing Security And Risk in A Global Supply Chain. Forrester. 2007.
12. Datta P, Christopher M.G. Information Sharing and Coordination Mechanisms For Managing Uncertainty in Supply Chains: A Simulation Study. International Journal of Production Research 2010: 1-39.
13. Centre for Research on the Epidemiology of Disasters. EM-DAT: the OFDA/CRED International Disaster Database. 2004.
14. Giunipero L.C, Eltantawy R.A. Securing The Upstream Supply Chain: A Risk Management Approach International Journal of Physical Distribution & Logistics Management 2004:698-713.
15. Gonkar R, Viswanadham N. Robust Supply Chain

Design: Strategic Approach For Exception Handling. Paper read at International Conference On Robotics & Automation, at Taiei,Taiwan. 2003.
16. Aberdeen Group, Global Supply Chain. Benchmark Report. 2006.
17. Gunasekaran A, Ngai E.W.T. Build To Order Supply Chain Managment:A Literature Review And Framework For Development. Operation Management 2005; 23: 423-451.
18. Hannon D. Survival Lessons From Automotive Buyers. Journal of Purchasing 2008; 137: 51-56.
19. Helferich O.K., Cook R.L. Securing The Supply Chain. Concil of Logistics Management, Oak Brook. 2002.
20. Hendricks K.B., Singhal V.R. An Empirical Analysis Of The Effects Of Supply Chain Disruptions On Long-Run Stock Price Performance And Equity Risk Of The Firm. Production and Operations Management 2005;14: 35-52.
21. Hendrik K, Singhal V. An Empirical Analysis of The Effect of Supply Chain Disruptions on Long-run Stock Price Performance and Equity Risk of The Firm. Journal of Production and Operations Management 2005; 14: 25-53.
22. Kleindorfer P.R., Saad G.H. Managing Disruption Risks in Supply Chains. Production and Operations Management 2005; 1: 53-68.
23. Kouvelis P, Chambers C, Wang H. Supply Chain Management Research And Production And Operations Management: Review, Trends And Opportunities Production and Operations Management 2006; 15: 44-69.
24. Lee H. Aligning Supply Chain Strategies With Product Uncertainties. California Management Review 2002; 44: 105-109.
25. Lee H., Padmanabhan V, Whang S. Information Distortion in a Supply Chain: the Bullwhip Effect. Management Science 1997; 43:93-102.
26. Lee H., Walfe M. Supply Chain Security Without Tears. Supply Chain Management Review 2003; 12-20.
27. Lee H.L., Billington C. Managing Supply Chain Inventory: Pitfalls and Opportunities. Sloan Management Review 1992; 65-73.
28. Levy D.L. International Sourcing and Supply Chain Stability. Journal of International Business Studies 1995; 2: 343-360.
29. Li X., Wang Q. Coordination Mechanisms of Supply Chain Systems. European Journal of
30. Operational Research 2007; 179: 1-16.
31. Manju I., Mentzer J.T. Global Supply Chain Risk Management Journal of Business Logistics. 2008; 29: 133-156.
32. Parmar, D. Mitigating Supply Chain Distribution Risk Using Sense And Respond Framework, ARIZONA STATE UNIVERSITY. 2007.
33. Rice J.B., Caniato F. Building a Secure And Resilient Supply Network. Supply Chain Management Review2003; 22-30.
34. Sheffi Y. Supply Chain Management Under The Threat Of International Terrorism. The International Journal of Logistics Management 2001; 12: 1-11.
35. Sheffi Y.The Resilient Enterprise: Overcoming Vulnerability for Competetive Advantage. THE MIT Press. 2005.
36. Soroor J., Tarokh M.J. Innovative SCM–A wireless Solution to Smartly Coordinate the Supply Processes Via a Web-Based, Real-Time System. The Journal of Information and Knowledge Management Systems 2006; 36:304-340.
37. Soroor J., Tarokh M.J., Shemshadi A. Theoretical And Practical Study of Supply Chain Coordination Journal of Business & Industrial Marketing 2009;24: 131–142.
a) Staar R., Newfrock J., Delurey M. Enterprise Resilience:Managing Risk in the Networked Economy. Strategy and Business. 2003.
38. Sterman A., John D. Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. Management Science 1989; 35 (3): 321-339.
39. Stevens G. Integrating the Supply Chain. International Journal of Physical Distribution & Logistics Management 1989; 19: 3 – 8.
40. Tang C.S. Robust Strategies For Mitigating Supply Chain Disruptions. International Journal of Logistics: Research and Applications 2006; 9:33-45.
41. Ting T.T., Khoo K.T. Reciever-Oriented "Pull" Model For RosettaNet Trade Documents Interchange. eprints.usm.my/ 2007.
42. Tyan J.C., Wang F-K., Du T.C. An Evaluation of Freight Consolidation Polices In Global Third Party Logistics. OMEGA 2003; 31: 55-62.
43. Wagner S., Neshat N. Assessing The Vulnerability of Supply Chains Using Graph Theory. International Journal of Production Economics 2009.
44. Wilson M. The Impact Of Transportation Disruptions on Supply Chain Performance. Transportation Research 2007; 43: 295-320.
45. Yao Y., Dresner M. The Inventory Value of Information Sharing, Continuous Replenishment, And Vendor Managed Inventory. Transportation Research Part E: Logistics and Transportation Review. 2007.
46. 46. Yusuf Y.Y, Gunasekaran A, Adeleye E.O, Sivayoganathan K. Agile Supply Chain Capabilities: Determinants Of Competitive Objectives. European Journal of Operational Research 2004; 159: 379–392.
47. Zsidisin G. Business and Supply Chain Continuity. Critical Issue Report. 2007.

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