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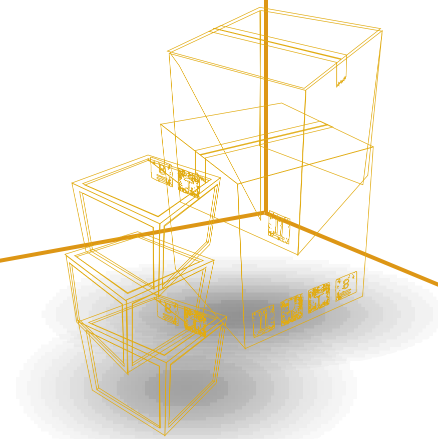

Inventory Control Models towards Physical Internet: Lateral Transshipment Policy Determination by Simulation

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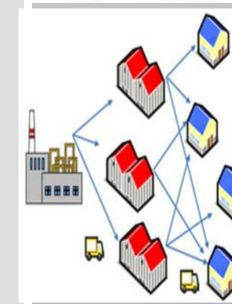
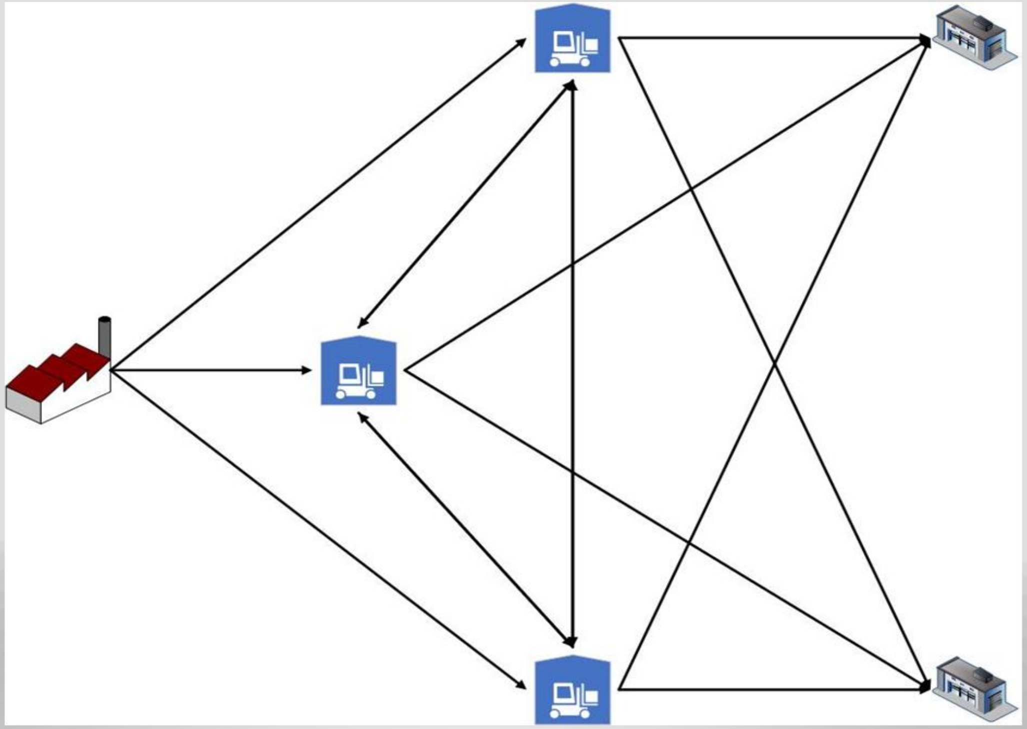
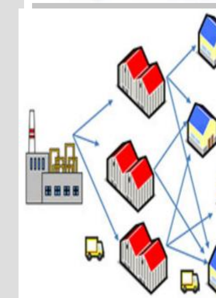


Two-echelon Network

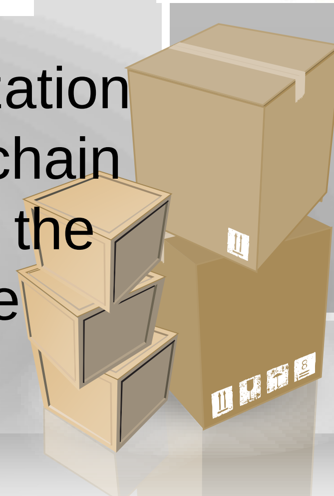


Main warehouse | Distribution hubs | Retailers

Inventory Control



By the recent technological development, realization of horizontal integration throughout the supply chain is possible. Hence, the management as well as the inventory control policy of a supply chain can be performed more efficiently.



Connected Network

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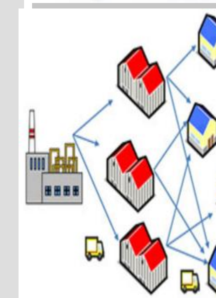
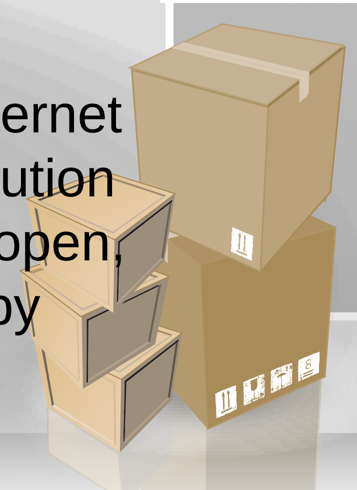


An innovative supply chain network is a Physical Internet (PI) philosophy oriented network in which the distribution and storage system is transformed into a common, open, interconnected logistics network of PI hubs shared by numerous companies.



Studied Network

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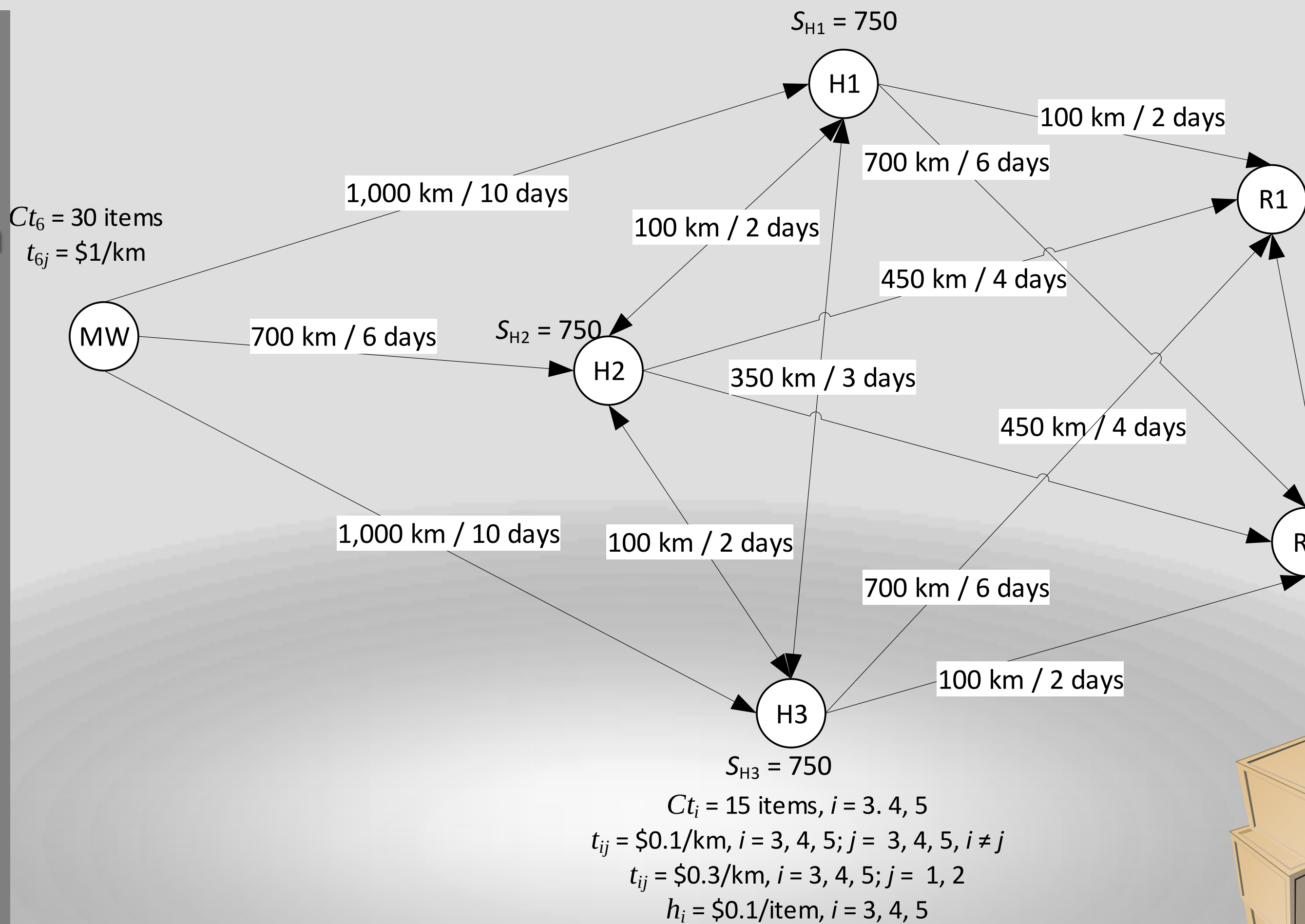
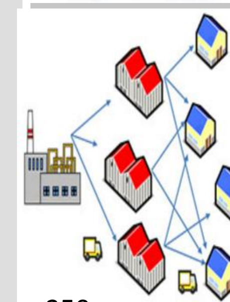
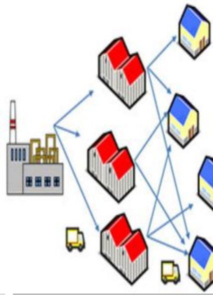
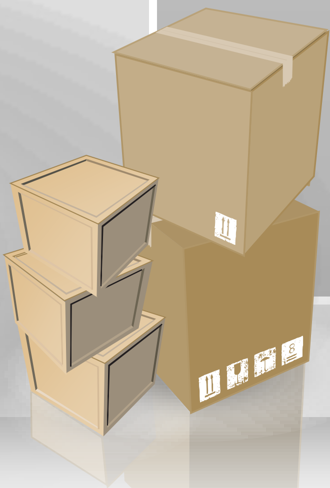




Lateral Transshipment

- Reactive transshipment
- Proactive transshipment
- Hybrid transshipment

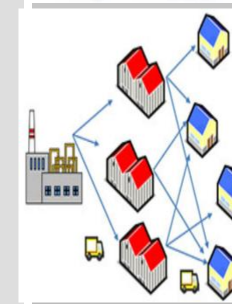




Literature

There are quite different opportunities to analyze the effects of PI-enabled logistics network on the decisions of supply chain management.

Our aim is to increase the knowledge on the assessment of the PI-enabled supply chain management by studying different transshipment policies on a two-echelon supply chain network.



Simulation Modeling of the System

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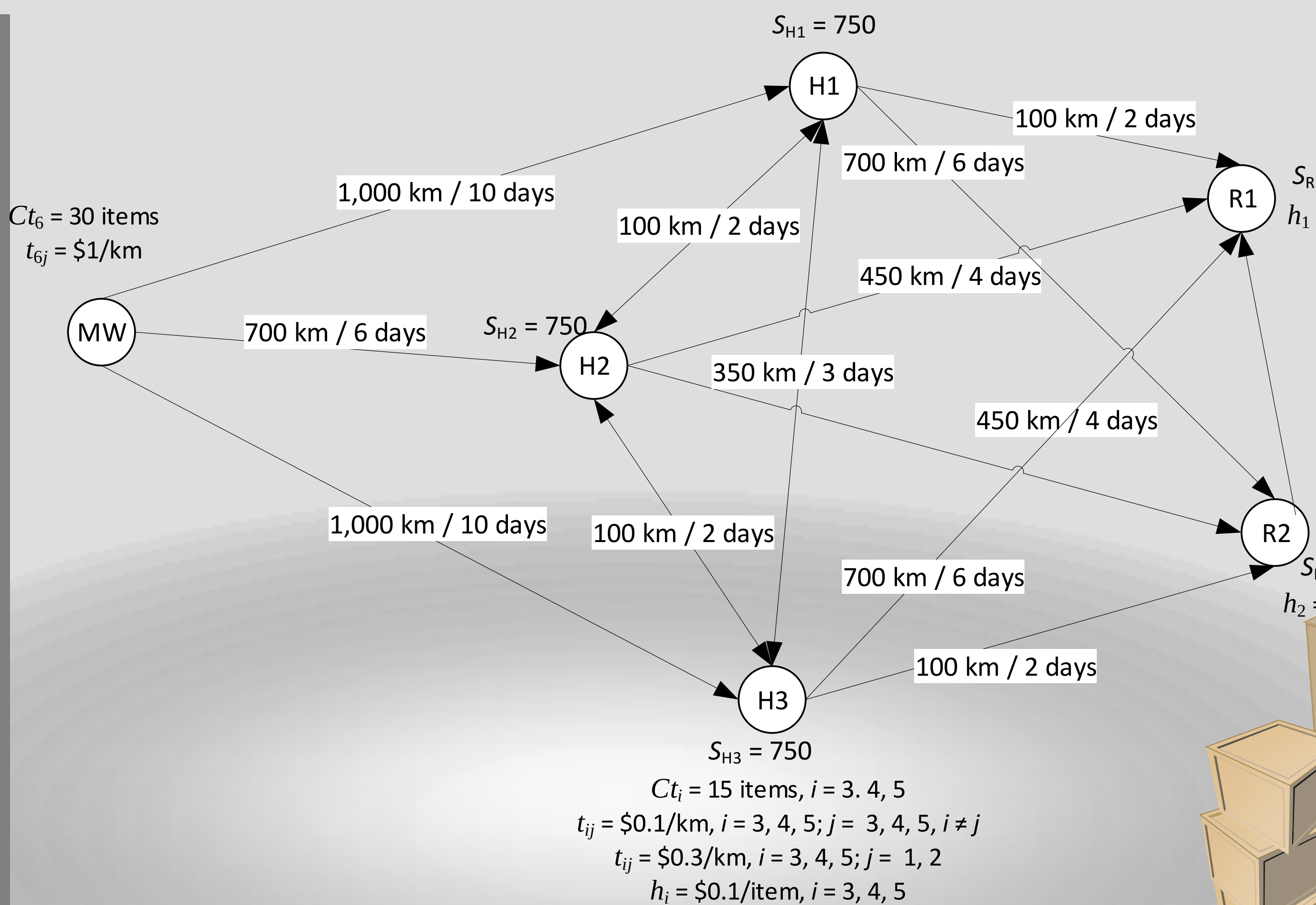
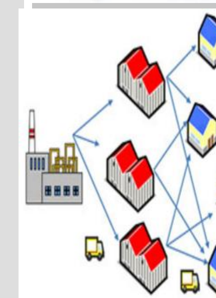
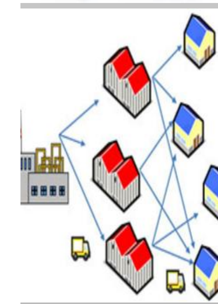




Notations

ss_{Ri} : safety stock level of retailers, $i = \{1, 2\}$
ss_{Hj} : safety stock level of hubs, $j = \{1, 2, 3\}$
S_{Ri} : up-to level of retailers, $i = \{1, 2\}$
S_{Hj} : up-to level of hubs, $j = \{1, 2, 3\}$
α : coeffcient for calculating share amount of items in hubs in reactive policy
β_1 : inventory level check coefficient for proactive policy
β_2 : coeffcient for calculating share amount of items in hubs in reactive policy
I_{it} : inventory level of retailer $i = \{1, 2\}$ or hub $i = \{3, 4, 5\}$ at the end of day t
D_{it} : demand amount arriving at retailer i, at the beginning of day t, $i = \{1, 2\}$
TC : total cost
h_i : holding cost per item at retailer $i = \{1, 2\}$ or hub $i = \{3, 4, 5\}$
Ct_i : truck capacity in hubs $i = \{3, 4, 5\}$ or main warehouse $i = \{6\}$
t_{ij} : transportation cost from MW, $i = \{6\}$ or transshipment cost from hubs $i = \{3, 4, 5\}$ to any location in the network
d_{ij} : distance (km.) from location i to location j, $i, j = \{1, 2\}$ for retailers; $i, j = \{3, 4, 5\}$ for hubs, and $i, j = \{6\}$ for MW
Q_{it} : order amount of retailer i, $i = \{1, 2\}$ or hub $i = \{3, 4, 5\}$ at the end of day t
q_{ji} : amount of transshipment from hub j to hub i where $j \neq i$
b_i : backorder amount at day t at retailer i, $i = \{1, 2\}$
tp : review period (i.e., days) for proactive lateral transshipment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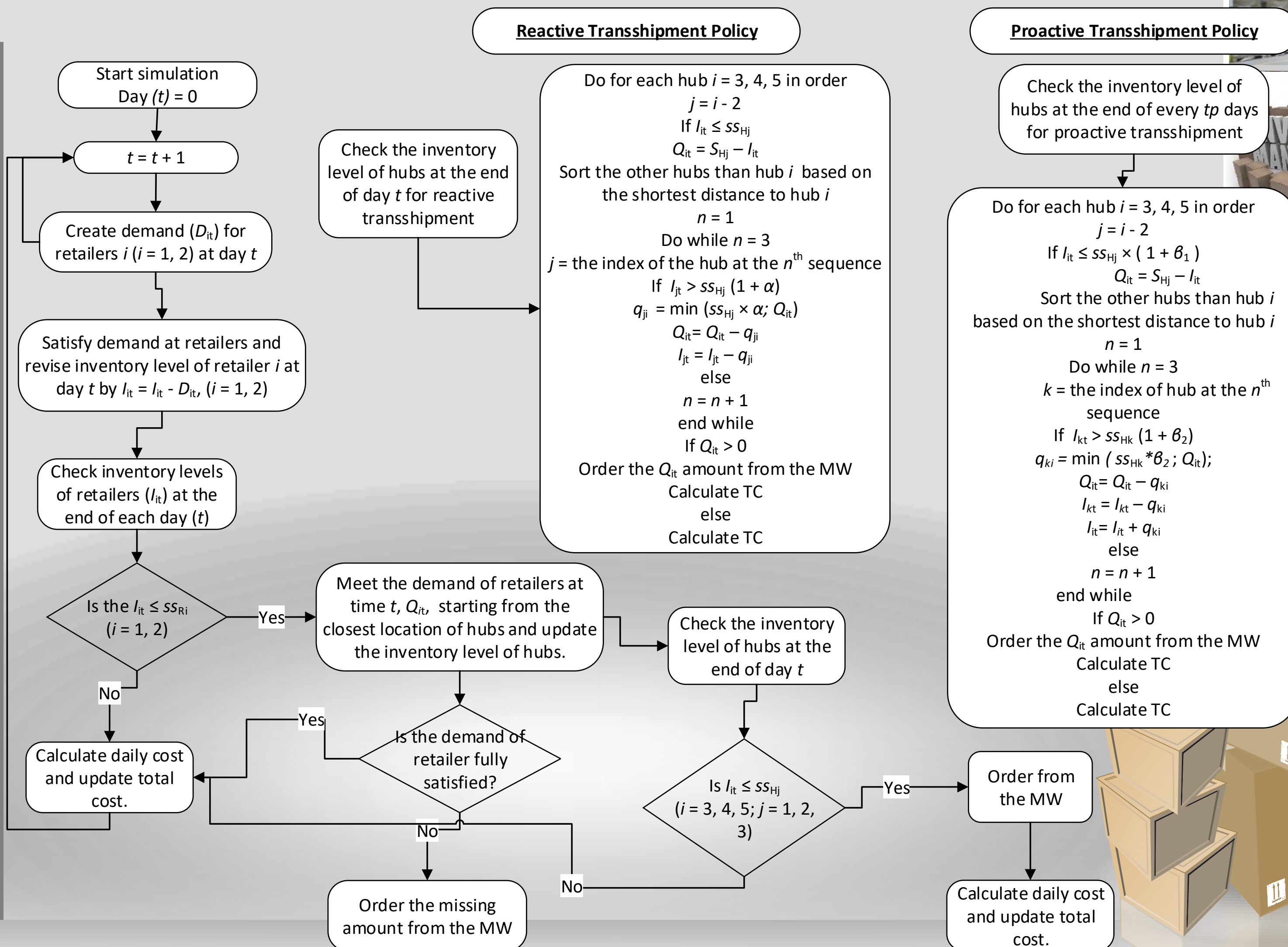

Reactive Transshipment

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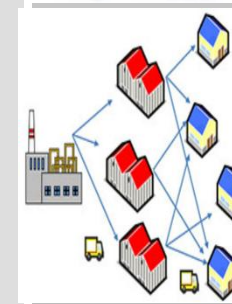
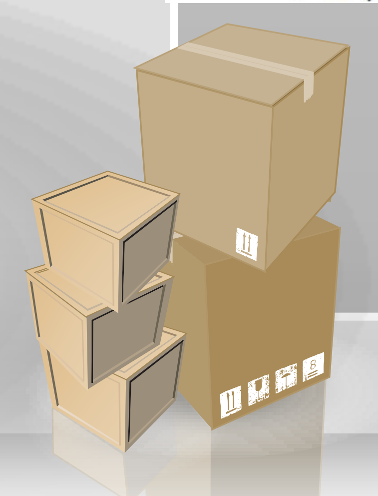
The reactive transshipment policy is considered that it takes place for only hubs. At the end of each day, the current inventory level of hubs is checked in the order of H_1, H_2 and H_3. Based on the (s, S) inventory control problem, the order amount for lateral transshipment or MW is calculated by:

$$Q_{it} = \begin{cases} S_{Hj} - I_{it} \text{ } if \text{ } I_{it} \le ss_{Hj}, i = j = 3, 4, 5 \\ 0, \quad otherwise \end{cases}$$



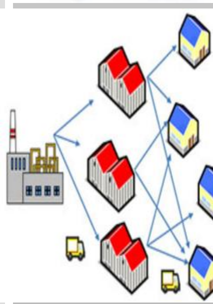


Reactive Transshipment

The transshipment amount from hub *j* to hub *i*, q_{ji}, is calculated by:

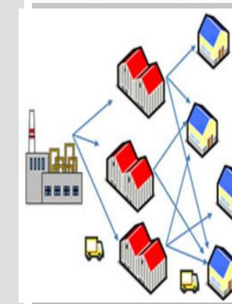
$$q_{ji} = \min\,(ss_{Hj} \times \alpha,\ Q_{it}),$$

where $I_{jt} \geq ss_{Hj} \times (1+\alpha)$. In reactive policy, when a hub's inventory level decreases to a level lower than its safety stock level, then another hub may make lateral transshipment in the amount of α coefficient of its safety stock level or Q_{it} amount where $0 \leq \alpha \leq 1$. The minimum amount is selected to be sent by the hub.



Proactive Transshipment

Note that the review period for proactive lateral transshipment policy is *tp* which is also considered to be a decision variable in the optimization procedure. The proactive lateral transshipment takes place only among the hubs. Every *tp* day, lateral transshipment may take place when the inventory level of hub *i* reaches to a lower level of coefficient - *β*1 - of its safety stock level: $I_{it} \leq ss_{Hj} \times (1 + \beta_1)$, where $0 \leq \beta_1 \leq 1$, $i = 3, 4, 5$. The order amount for hub *i* is calculated as in Qit. However, the transshipment amount from hub *k* to hub *i*, q_{ki}, $k \neq i$, $k = 3, 4, 5$ is calculated by

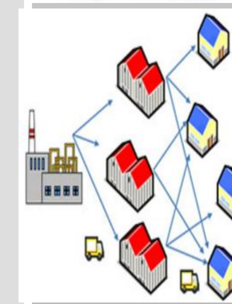


Proactive Transshipment

If $I_{kt} > ss_{Hk}(1 + \beta_2)$

$q_{ki} = \min(ss_{Hk} {}^{*}\beta_2 ; Q_{it})$,

meaning that in a lateral transshipment, from a hub, β_2 times of its safety stock level or Q_{it} amount of inventory level can be sent. The minimum amount is selected to be sent by the hub.



Simulation Assumptions

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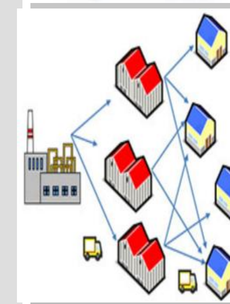
- Demands arrive at the retailers, R1 and R2, at the beginning of each day with stochastic amounts.
- Demand amounts for R1 and R2 are considered to be normally distributed with mean and standard deviation of (20, 5) and (30, 5), respectively.
- Safety stock levels of retailers and hubs, ss_{R1}, ss_{R2}, ss_{H1}, ss_{H2}, ss_{H3}, and the parameters, α, tp, β_1, and β_2 are considered as decision variables that are to be optimized in the models.



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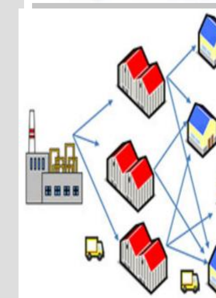
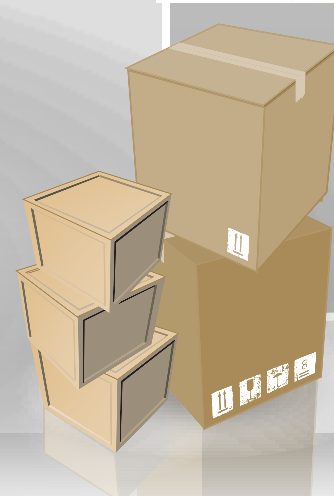
Retailers and hubs have capacity constraints in terms of the maximum number of items that they can store in their facilities. These values are assigned as up-to-levels of retailers (S_{Ri}) and up-to-levels of hubs (S_{Hi}) whose values are considered to be: $S_{R1} = S_{R2} = 250$; $S_{H1} = S_{H2} = S_{H3} = 750$, in Design 1 and $S_{R1} = S_{R2} = 250$; $S_{H1} = S_{H3} = 1000$; $S_{H2} = 1200$, in Design 2.





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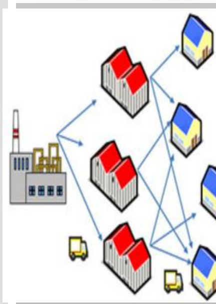
- Holding costs for retailers and hubs are $0.4/item and $0.1/item, respectively.
- In transportation from the MW, trucks have load capacity of 30 units. In transshipment among hubs, trucks have load capacity of 15 units. The transportation or transshipment cost is calculated based on the number of trucks.
- The simulation models are run for two years with 60 days of warm-up period for each scenario.
- The optimization is completed by minimizing the simulation run total cost by using the OptQuest tool in ARENA 14.0 commercial software.



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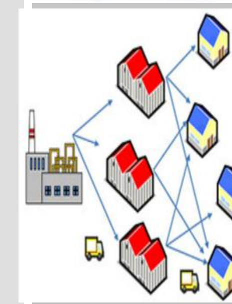
- No order is placed by the stocking locations if there is already on road.
- In each run, ten independent replications are completed.
- In the optimization, fill rate constraint is considered 0.95. Fill rate is defined as a rate at which customer orders can be filled from existing amount of inventory.
- Since it is a popular and useful variance reduction technique, Common Random Numbers (CRN) variance reduction technique is used in the simulation models.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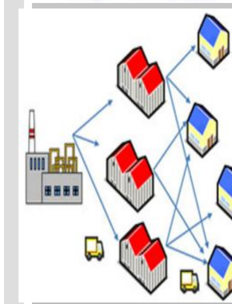
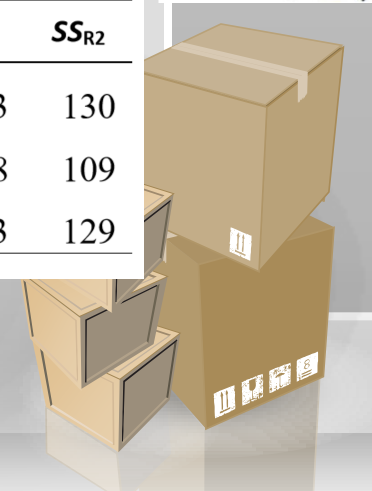
OptQuest results of transshipment policies based on two network designs

Design 1	α	β_1	β_2	tp	TC	SS_{H1}	SS_{H2}	SS_{H3}	SS_{R1}	SS_{R2}
Reactive	0.81	-	-	-	268,086	333	60	442	81	126
Proactive	-	0.44	0.01	7	300,677	340	133	601	80	121
Hybrid	0.04	0.28	0.05	5	287,399	265	44	362	81	115
No Lateral	-	-	-	-	318,495	293	26	407	81	109
Design 2	α	β_1	β_2	tp	TC	SS_{H1}	SS_{H2}	SS_{H3}	SS_{R1}	SS_{R2}
Reactive	0.88	-	-	-	417,103	361	72	406	83	130
Proactive	-	0.81	0.01	5	407,948	400	81	431	88	109
Hybrid	0.19	0.71	0.06	1	422,607	266	82	383	83	129

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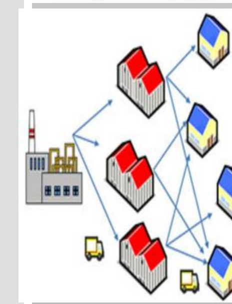
- In Design 1 network, the best transshipment policy takes place in the reactive policy.
- In Design 2 network, the best transshipment policy takes place in the proactive policy.
- When there is no lateral transshipment policy in the network (in Design 1), it has the largest total cost.

- The second hub's safety stock level is always lower compared to other hubs' safety stock levels. This is probably since this hub is located at the middle and it is the closest location to the MW. It tends to share its inventory with the other hubs in the lateral transshipment cases. Hence, by the decreased safety stock level, it carries more inventory to share with the other hubs.



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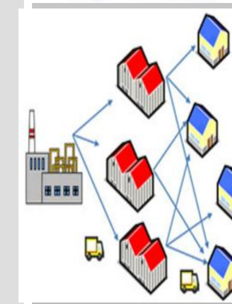

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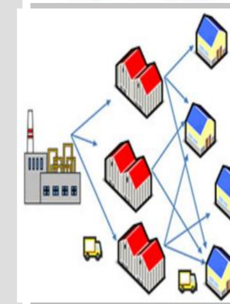
- By looking at the α and β_1 values, we understand that in Design 2, due to the increased values of them, it seems that more lateral transshipment takes places. This is probably because of the fact that, in Design 2, there are higher hub capacities compared to Design 1 and due to the higher transportation cost from hubs to retailers more lateral transshipment takes place. In this design, probably lateral transshipment takes place mostly from the second hub to the others. By that, it tends to keep more inventory in the Hubs 1 and 3, which are the closer hubs to the retailers.

Conclusion

In this work, we study mainly two lateral transshipment policies: reactive and proactive in a two-echelon supply chain network. We seek the best lateral transshipment policy based on two different network designs in terms of hub capacities and transportation cost from hubs to retailers.

We optimize the safety stock levels as well as some other transshipment related parameters such as α, tp, β_1, and β_2, by minimizing the total cost in the system.

In the total cost, we consider backorder costs in retailers, transportation, transshipment costs, and holding costs in hubs and retailers.



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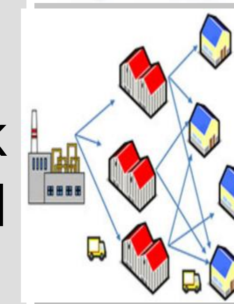

As a result of this study, it is observed that the performance of a lateral transshipment policy strongly depends on the studied network design and its parameter values as well as how the transshipment policies are pre-defined.

As a future study, we recommend more network design types to be studied with different lateral transshipment policies to test their performances.

It would be also interesting to analyze the effect of the demand profile (fast or slow moving items) on the transshipment policy determination on the studied networks.

Questions?

???QUESTIONS???

Thank You