Inventory Control under Possible Delivery Perturbations in Physical Internet Supply Chain Network

Maroua NOUIRI, Abdelghani BEKRAR, Damien TRENTESAUX

[1]LAMIH UMR CNRS 8201, University of Valenciennes and Hainaut-Cambrésis

IPIC Conference 18-22 June 2018, University of Groningen, the NETHERLANDS

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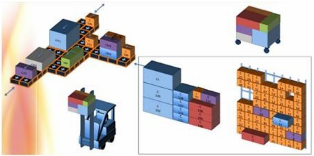
Introduction

✍ Logistics organizations are nowadays expected to be efficient, effective, and responsive while respecting other objectives such as sustainability and resilience.

✍ Sustainable supply chain management has become a crucial issue in recent years.

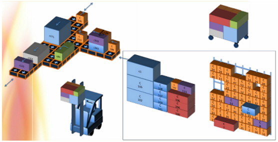


✍The "Physical Internet" was proposed by Montreuil, B. (2010) as a solution to the global logistics sustainability grand challenge.

Introduction

✍ Inspired from the digital internet, the Physical Internet is defined as an open and shared network that interconnect independent logistics networks and services.

✍ The smart PI-containers, the PI-nodes and the PI-movers are the key types of Physical Internet are key economic driver for society.



Highlights

➵ The interest of the PI concept on resilience and sustainability in logistics management, when facing perturbations in delivery control model.

➵ Two Multi agents based simulation models have been proposed.

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State of the art

Standardized of PI-components and functional design facilities

✍ Montreuil et al, (2012) provide the PI concepts and foundations similar to the Open Systems Interconnection (OSI) model for the Digital Internet.
✍ Montreuil et al.(2012) proposed an Open Logistics Interconnection (OLI) model for the Physical Internet.
✍ Lin et al. (2014) designed Physical Internet container sets.

Evaluate the performance of the physical internet on logistics

✍ Pach et al. (2014), Walha et al. (2014) and Chargui et al. (2018) studied the PI-containers' internal routing problem in PI-hubs (road-rail, road-road, etc).
✍ Pan et al. (2015) and Yang et al (2015) treated the external routing problem (PI-hubs interconnection).

State of the art

The inventory control problem

✍ Yang et al (2015) : proposed a mathematical model for the inventory problem and a simulated annealing heuristic.
✍ Pan et al (2015) presented a simulation study for inventory control in the classical supply chain and the Physical Internet supply chain.
✍ Yang et al (2017) have proposed a multi-agent simulation model for the resilience of freight transportation in the Physical Internet while considering random disruptions at the hubs.

The scope

➽ Our research fits in the scope of evaluating inventory control's performances while considering external perturbations in routes.
➽ Two multi-agent based simulation models for both the classical and the Physical Internet supply chain are proposed.

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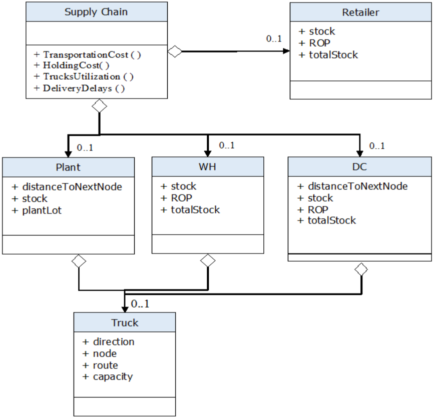
Two multi agent based Simulation models

- Class diagram of the classical supply chain Network

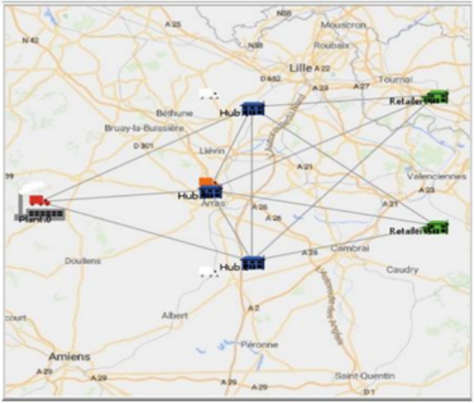


Two multi agent based Simulation models

- Classical Supply chain Network designed for simulation

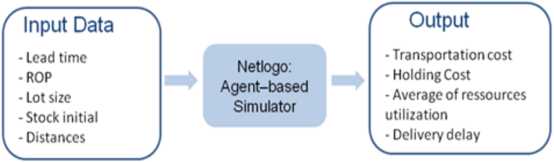
Two multi agent based Simulation models

- Physical Internet Supply chain Network designed for simulation



Two multi agent based Simulation models

- The main Input and Output data of the simulation process



- The lead time represents the time needed to deliver the goods to the customers.
- The lot size represents the quantity of product units used in the procurement process.
- The reorder point (ROP) represents a level of inventory which triggers a procurement order to replenish that particular inventory stock.

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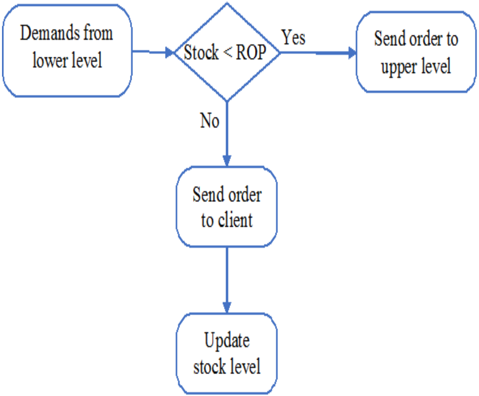
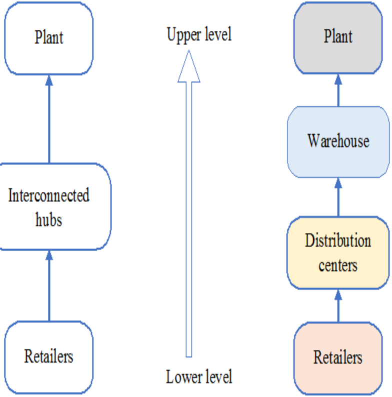
Inventory control algorithm

Classical Supply Chain

- the same proposed in Pan et al (2015)
- If the stock level is lower than the reorder point, an order of replenishment is sent to the upper level.



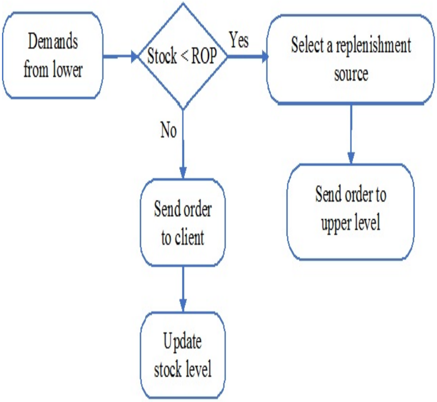


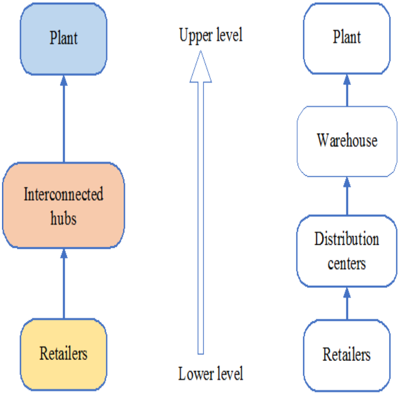
Inventory control algorithm

Physical Internet Supply Chain

✍ If the stock level is lower than the reorder point, there isn't only one upper level.

✍ The inventory model should select a replenishment source before sending the order.





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Simulation Scenarios

- Scenario 1 : Behavior with different number of trucks
  to integrate the change in the number of trucks and the capacity of each one.

Number of trucks and Capacity Level	Low	Medium	High
Low	(2, 20)	(2, 30)	(2, 40)
Medium	(5, 20)	(5, 30)	(5, 40)
High	(10, 20)	(10, 30)	(10,40)

External Perturbation

✍ We suppose that each node have the same number of trucks with the same capacity. ✍ The low Medium level means that the node have 2 trucks with 30 capacity intern of number of pallets except retailers.

Simulation Scenarios

- Scenario 2 : Behavior with different retailers demands

  Scenario that represents different types of retailer's strategy

Type	Daily demand	Periodic demand	Random
Demand of R1	Mean = 20, S.D. = 4	UNIF(20,40)	Rand (0, 45)
Demand of R2	Mean = 35, S.D. = 7	UNIF(20,40)	Rand (0, 45)

External Perturbation

✍ The two scenarios have been submitted to an external perturbation : incident is happen in the route that related two nodes.
✍ There are many type of perturbation's level that can occur :
- The low, medium and high level (1 or 8 days delayed).

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The key performances indicators

- The Holding cost :

$$HoldingCost = Volume * days * p \ (€/\text{day} \ \ m^3)$$

  - The parameter p : refers the cost per day which is equal to 0.11 (€/day m^3) at the warehouse, distribution center and hub level and 0.165 (€/day m^3) at the Retailer's.
  - The variable *days* takes 1 value if stocks are present at a hub at day i, otherwise it takes 0.
  - The parameter unit is measured in a full pallet (which is 1.73 m^3).

The key performances indicators

- The transportation Cost :

$$TransportaionCost = distance * p \ (\text{€/km})$$

  - We suppose that there is full truckload transportation in the case of Fast Moving Consumer Goods FMCG supply chain.
  - The parameter *distance* represents the distance traveled by the truck.
  - The parameter *p* equals to 1.4 (euro/km) taken from Pan et al (2015).

The key performances indicators

- The trucks utilization

$$UtilisationRate = \frac{nbtrucks_{used}}{nbtrucks_{total}} * 100$$

  - we suppose that each node have its own fleet of trucks.
  - The number of trucks used is calculated as follows :

$$nbtrucks_{used} = \frac{ordered_{quantity}}{trucks_{capacity}}$$

- The average of utilization rate

$$AverageUtilizationRate = \frac{UR_{plant} + UR_{WH} + UR_{DC1} + UR_{DC2}}{4}$$

The key performances indicators

- The average of delivery delays

$$Average_{deliverytime} = \frac{\sum(deliverytime - leadtime)}{Number_{days}}$$

  - The deliverytime is the real amount of time that goods take to arrive at their destinations.
  - The leadtime is a predefined time needed to deliver the goods.

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Experimental results

- Scenario 1 : varying number of trucks and capacities

✍ In this case, the retailer's strategy demand is daily.

Level	Holding Cost (euro)		Transportation Cost (euro)		Trucks Utilization (%)		Average Delivery Delays	
	CSC	PISC	CSC	PISC	CSC	PISC	CSC	PISC
(2, 20)	69.1	52.3	2212.23	2085.79	48.62	47.52	0.02	0
(2, 30)	69.89	57.21	1582.93	1264.87	31.14	32.7	0.04	0
(2, 40)	71.82	52.64	1224.53	1501.47	21.72	19.87	0.16	0
(5, 20)	66.11	53.98	2315.37	2715.82	20.35	20.3	0.13	0.01
(5, 30)	69.27	69.36	1628.2	1527.2	12.84	12.84	0.1	0
(5, 40)	69.24	66.98	1342.6	1342.6	9.5	10.24	0.05	0
(10, 20)	65.66	45.76	2398.9	2808.9	10.49	10.49	0.2	0.009
(10, 30)	75.14	74.34	1353.8	1214.8	5.32	4.79	0.26	0
(10, 40)	66.45	56.45	1452.73	1172.73	5.12	4.08	0.33	0

Interpretation

➠ Improvements in differents KPI value due to the new connections related between hubs. ➠ When testing the low high level (2, 40), the holding cost is decreased from 71.82 euro to 52.64 euro ➠ The average of delivery delays is around to zero. In fact, the physical internet paradigm allows new routes between logistics centers

Experimental results

- Scenario 2 : varying retailer's strategy demand

✍ The low high level in term of combination (truck, capacity) is used (20, 40).

Level	Holding Cost		Transportation Cost		Trucks Utilization		Delivery	
	CSC	PISC	CSC	PISC	CSC	PISC	CSC	PISC
Daily Demand	71.13	59.1	1288	1207.3	22.7	19.65	0.18	0
Periodic Demand	56.94	48.3	1878.33	1645.32	33.32	28.89	0.06	0
Random Demand	102.92	98.45	95.67	76.23	1.779	2.69	0.17	0

Interpretation

➠ Main improvements are performed in daily demands. In fact the holding cost is reduced from 71.13 euro to 59.1 euro.
➠ The The transportation cost is reduced from 1288 euro to 1207.3 euro.
➠ The average of delivery delays is around to zero in the physical internet supply chain when facing perturbations in routes.

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Conclusion and Future works

- Conclusion
  - Two multi-agent simulation models were developed to test the performance of both the classical and the Physical Internet supply chain.
  - KPI used : transportation cost, holding cost, resources utilization and delivery delay.
  - Different scenarios have been performed by varying the number of trucks and their capacities, the retailers' demand strategies and the level of perturbations.
  - The results showed that the physical Internet supply chain is more efficient compared to classical supply chain.
    - The Holding cost, the transportation cost, the average truck utilization and the average of delays are improved.
- Interesting direction for future researches
  - The simulation of the effect of PI on SCN composed from many plants and grouping centers while considering various types of products and external routing constraints for trucks between hubs while considering perturbations and time windows.

Thank You For Your Attention...

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M. Nouiri, A. Bekrar, D. Trentesaux,

maroua.nouiri@univ-valenciennes.fr