IPIC 2016

Workshop WA3:
Resilience of Physical Internet Networks

Network resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.

The ResiliNets Research Initiative definition of **resilience**

Towards a smart hyperconnected era of efficient and sustainable logistics, supply chains and transportation

IPIC 2016 - 3rd International Physical Internet Conference

June 29-July 1, 2016 | Atlanta, GA USA

Resilience of Physical Internet Networks

Agenda:

- **Presentation**

  Performance evaluation of interconnected logistics networks confronted to hub disruptions

  Yanyan Yang, Shenle Pan and Eric Ballot

- **Discussion**

Resilience of Physical Internet Networks

Towards a smart hyperconnected era of efficient and sustainable logistics, supply chains and transportation

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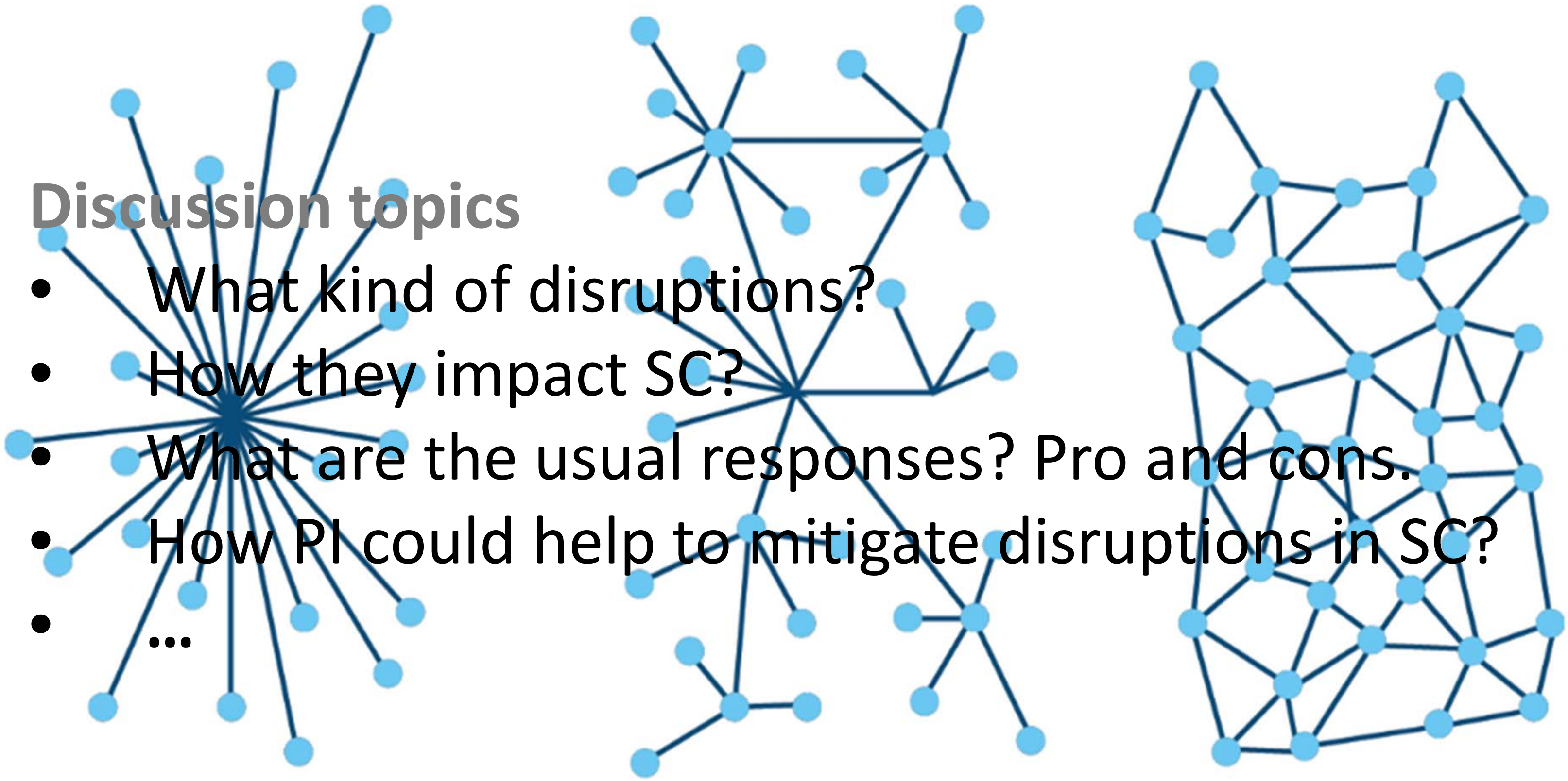
Resilience of Physical Internet Networks



Discussion topics

- What kind of disruptions?
- How they impact SC?
- What are the usual responses? Pro and cons.
- How PI could help to mitigate disruptions in SC?
- …

Performance evaluation of interconnected logistics networks confronted to disruptions at hubs

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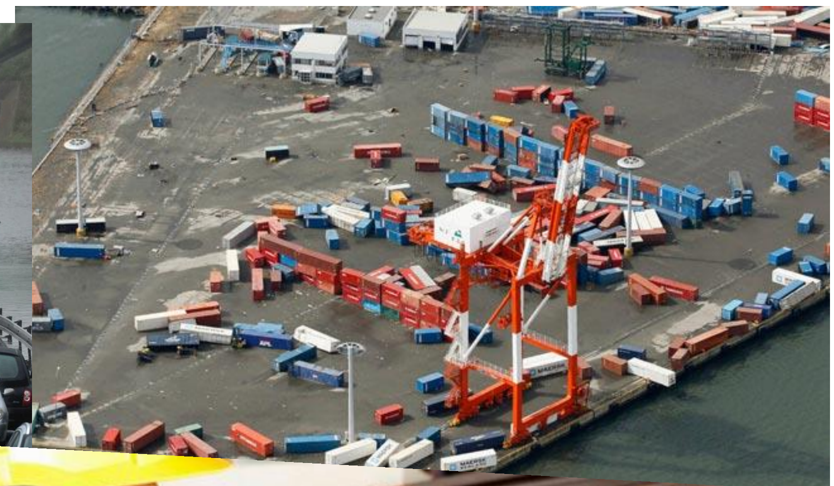
Plan

- Context
- Research questions and methodology
- Simulation model
- Numerical study: Case studies of mass distribution in France
- Conclusion and perspectives

Context

Introduction to Supply Chain Disruptions

- Supply chain disruption: unplanned events that hamper supply chain systems (Craighead et al. 2007; Ivanov, Sokolov, and Dolgui 2014).
- Causes: natural disasters, terrorists attacks, labour strikes, facilities/transportation failures, machine breakdowns, and etc.

Context

Introduction to Supply Chain Disruptions Risks

- *Supply Chain Resilience* survey 2013 on 519 companies from 71 countries:

1) 75% experienced at least 1 disruption per year
2) 15% experienced disruptions with cost > €1M.

Current independent heterogeneous logistics networks: restrictive, specialized logistics services

Inventory redundancy:(Groenevelt, et al. 1992)

Sourcing flexibility:(Tomlin 2006)

Facility location problem: (Snyder and Daskin 2005)

Interactions with external stakeholders: (Gümüs, Ray, and Gurnani 2012)

Interconnection of logistics networks

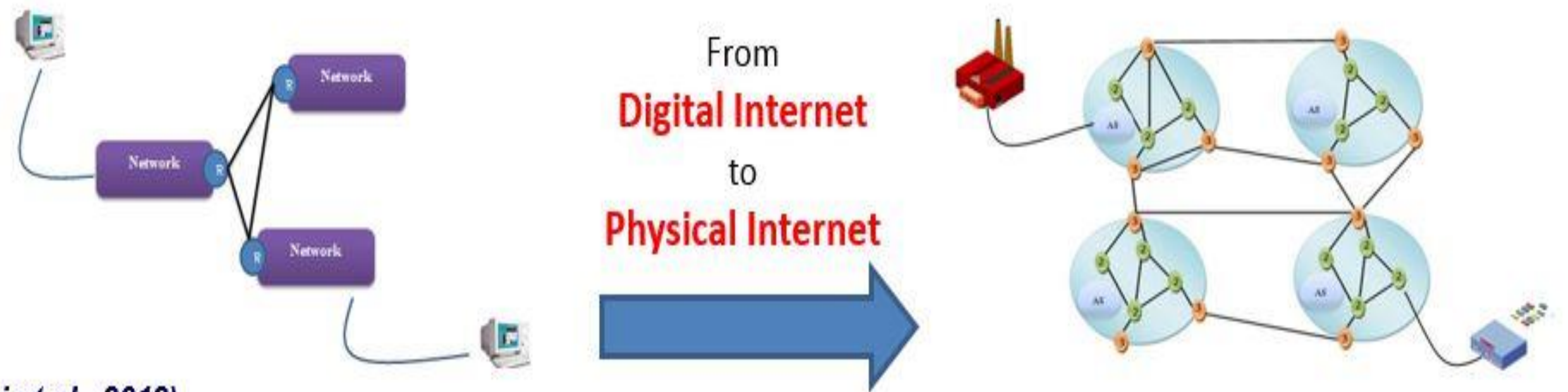
- Physical Internet (Ballot and Montreuil 2014)

Mitigate disruption risks by open interconnected logistics services

Context

Physical Internet

- Using the Digital Internet as a Metaphor for the Physical World
- An open and interconnected global system through a standard set of modular containers, and routing protocols and standards (Ballot and Montreuil 2014).



(Sarraj et al., 2012)

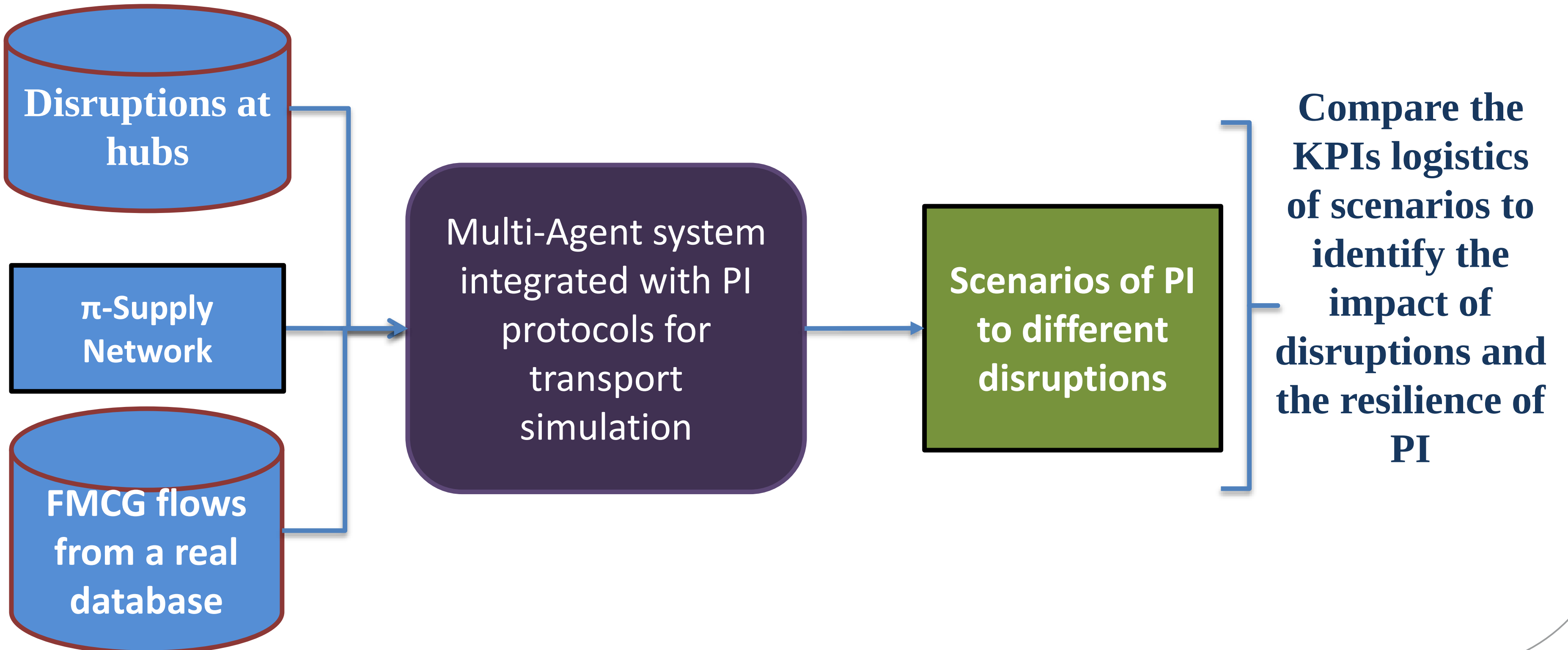
A quantitative study on the resilience of PI, which is defined as performance of PI confronted to disruptions at hubs

Research questions and methodology

Research questions:

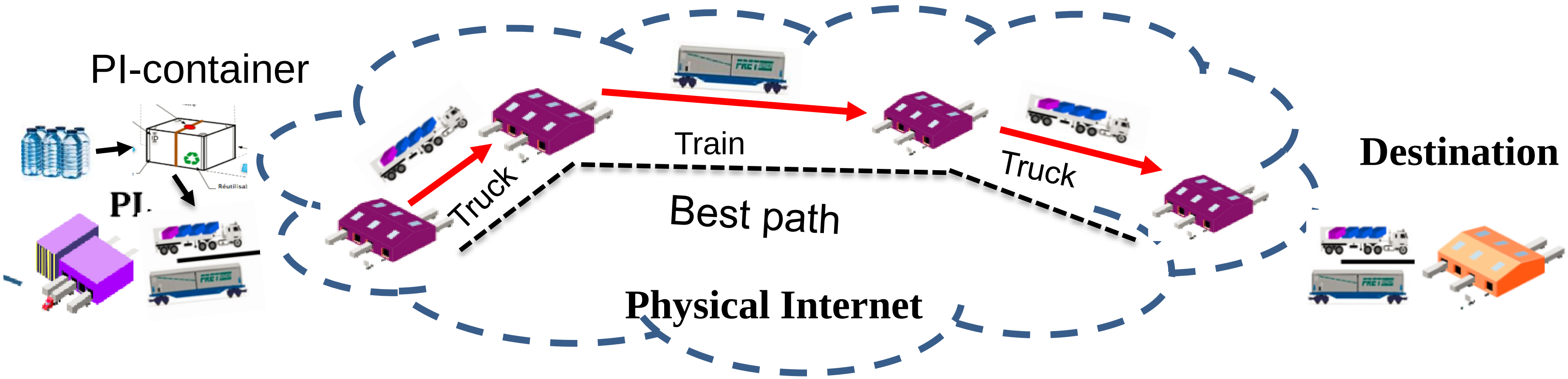
1) What protocols should be applied when confronted to disruptions at hubs?
2) What's the resilience of PI?

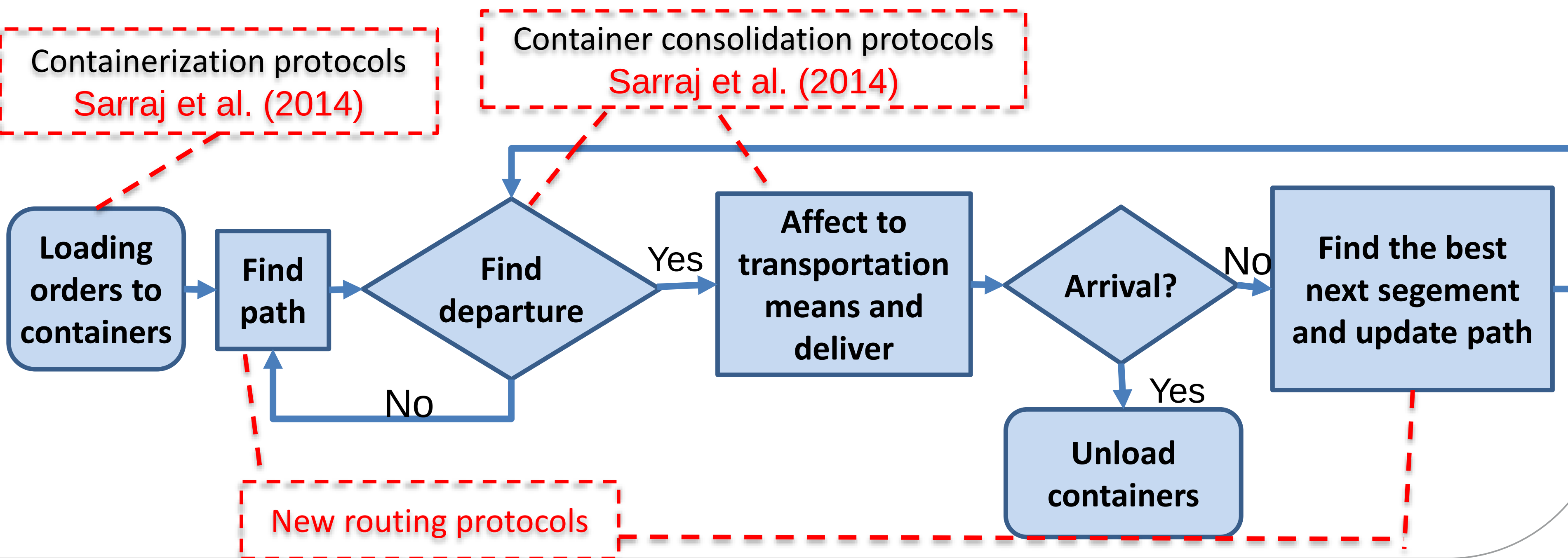
Methodology: a simulation approach



Simulation model

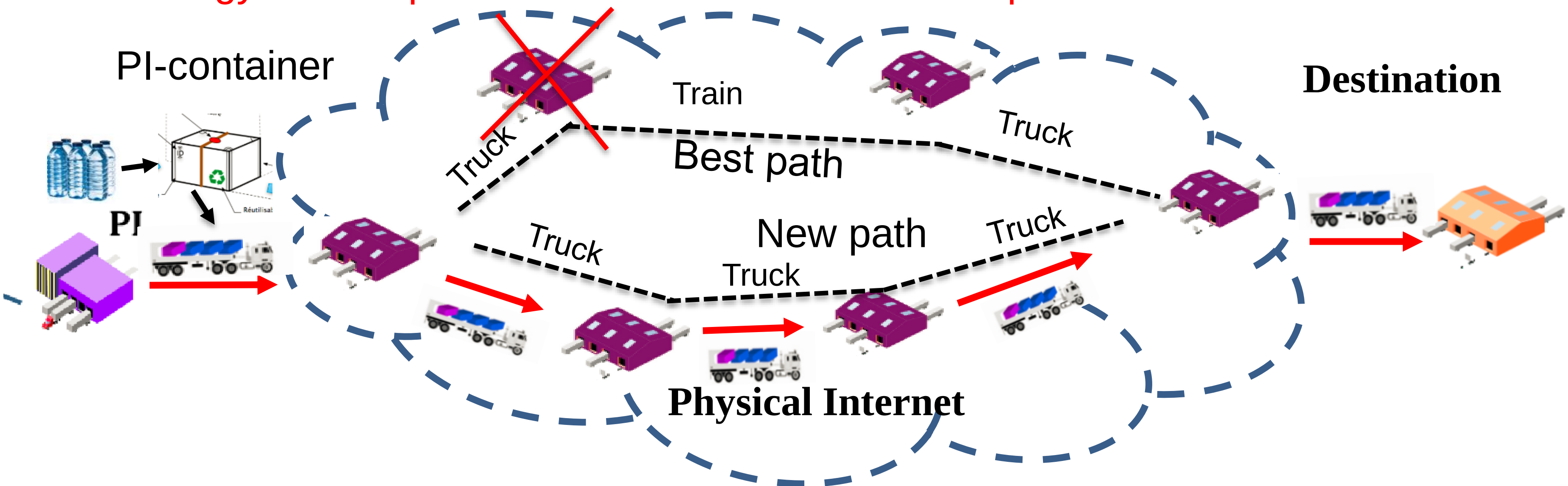
Extension of multi-Agent transportation system in Sarraj et al. (2014)



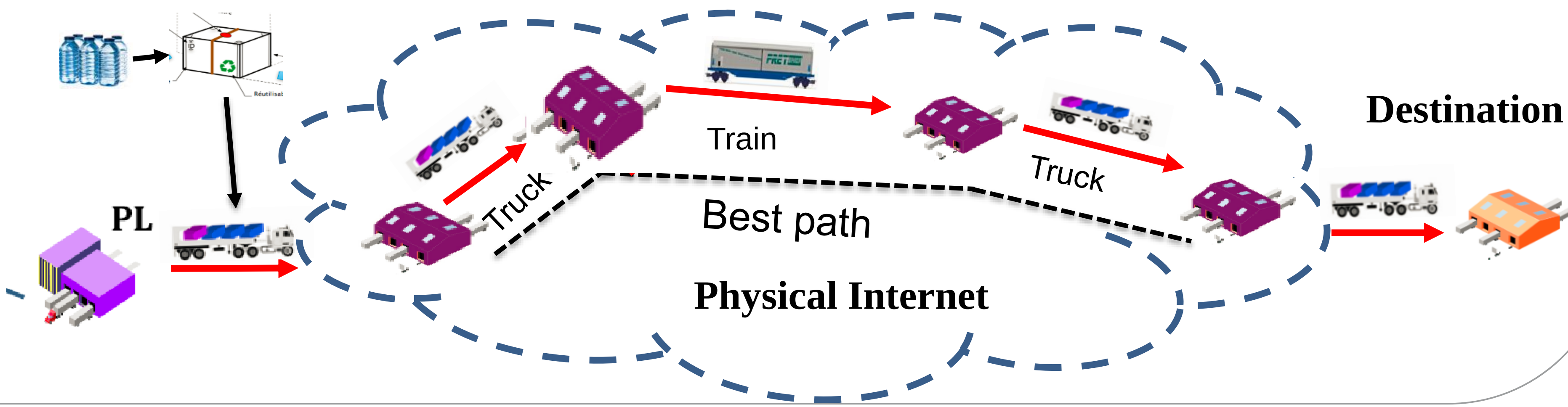


Simulation model –Disruption protocols

- Strategy 1: Disruptions avoidance – avoid all disrupted hubs.



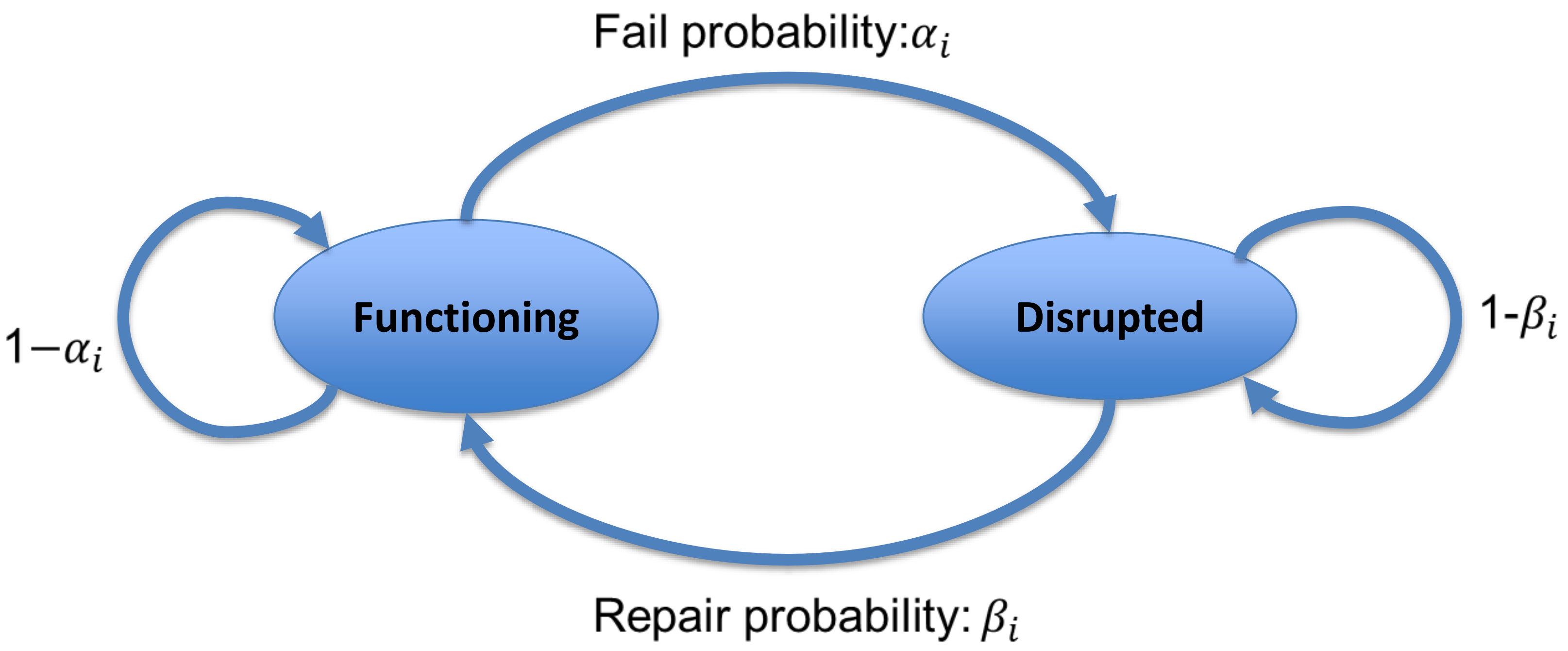
- Strategy 2: Risk-taking – Consider a penalty during time for disrupted hubs.



Simulation model

Simulating disruptions at hubs –Disruption agent

- Two-state Markov process.
- State review period: 1 hour
- When disrupted, all the logistics services at this hub are paralyzed until the disruption ends.
- The goods already at hubs are assumed not destroyed by the disruptions (labour strikes, machine breakdowns, etc.)



Numerical study

Input data:

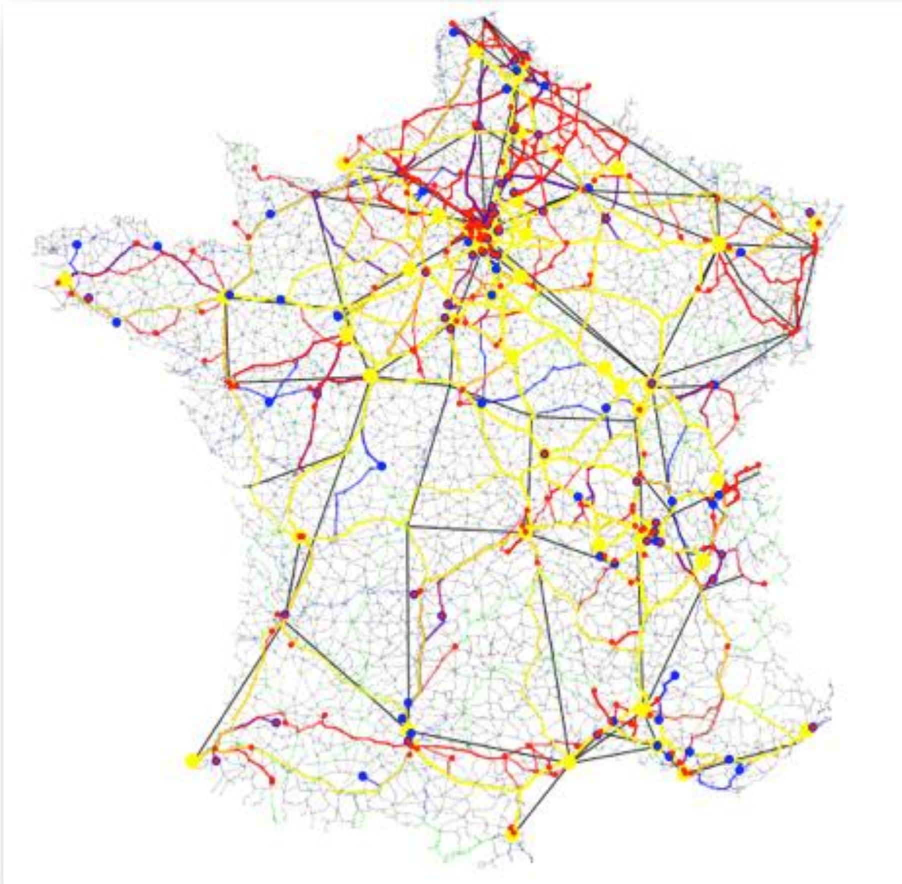
A real-world database from FMCG chains in France

- 2 retailers and their top 106 common suppliers

- 303 Plants, 57 WH and 58 DC.

- Flows of 13 weeks in 2009
  - *702 products*
  - *4 451 flows*
  - *2 582 692 full-pallets*
  - *211 167 orders*

- 47 π-hub implanted for road transport, 19 π-hub for multi-modal transport (road and railway)



Numerical study

Input data:

➢ Disruptions profiles by Snyder and Shen (2006):

Index	Fail probability	Repair probability	Av.During (hour)	Maximum During (hour)	Lost capacity of PI	Description
1	1%	30%	3,20	20	3%	Rare, very long
2	5%	50%	1,99	14	9%	Rare, long
3	5%	70%	1,42	8	7%	Rare, mi-long
4	10%	50%	1,99	14	17%	Less frequent, long
5	10%	70%	1,43	8	13%	Less frequent, mi-long
6	20%	50%	1,99	14	29%	Frequent, long
7	20%	70%	1,43	8	22%	Frequent, mi-long
8	20%	90%	1,11	5	18%	Frequent, short

➢ Routing agent:

❖ Best path: Dijkstra's Algorithm

❖ Two criteria for path optimization

- Minimization of lead time

- Minimisation of total distance travelled

Result analysis

Scenarios and main KPIs

For each type of disruptions:
Scenario index: Routing criteria. Disruption strategy. Disruption profile

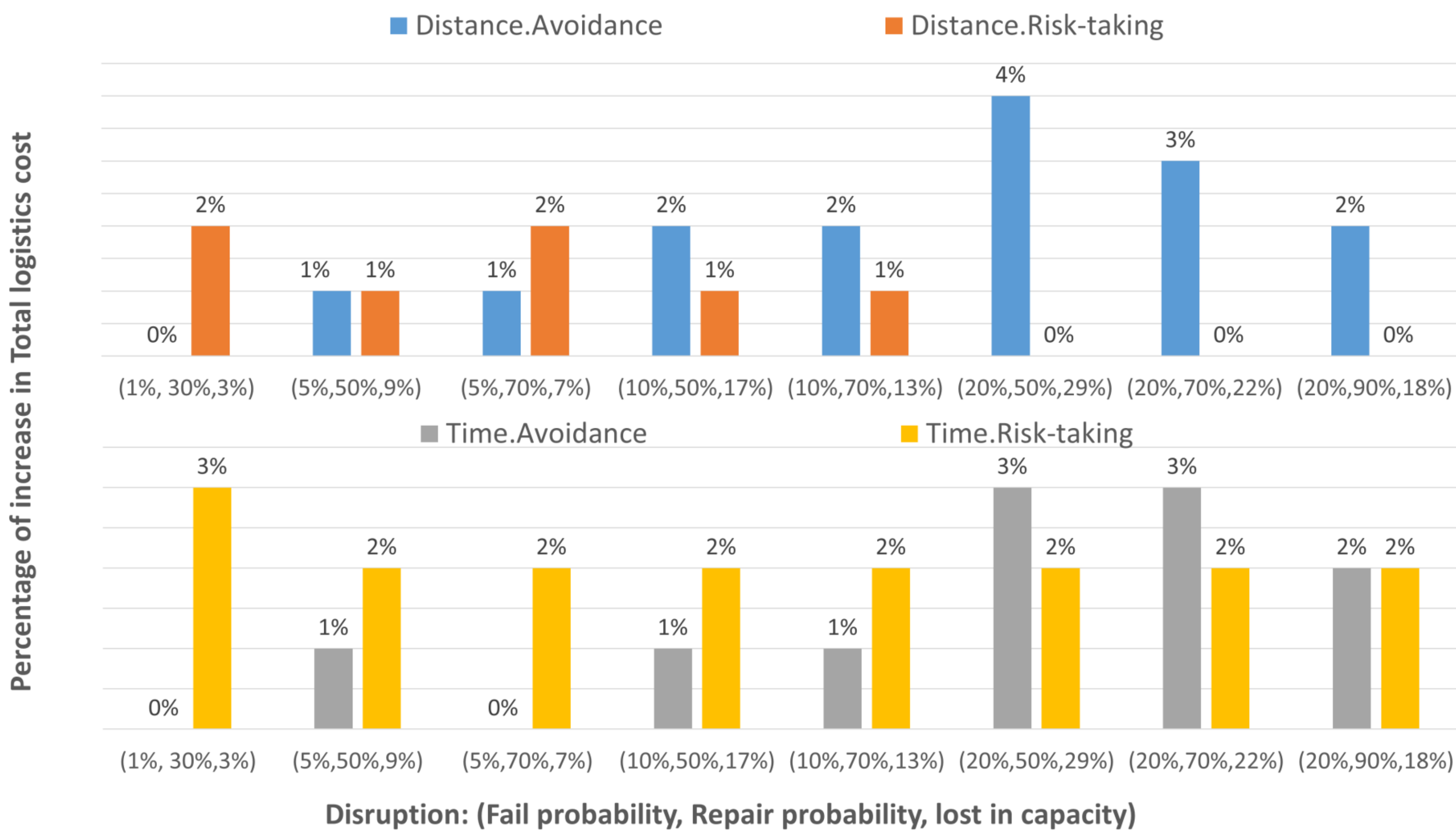
Main KPIs

Sce No.	Chains Structure	Transport mean	Disruption profile	Disruption strategy	Routing Criteria	Mean LT(h)	CO_2 t	Cost M€
0	PI-WH-DC	Truck			NA	5.86	52 742	81.98
1.0	PI-WH-DC	Truck/train			Distance	7.62	30 544	66.206
1.A.1	PI-WH-DC	Truck/train	1	Avoidance	Distance	7.8	30 925	66.526
1.R.1	PI-WH-DC	Truck/train	1	Risk taking	Distance	8.51	31 520	67.439
2.0	PI-WH-DC	Truck/train			Time	7.36	33 356	67.735
2.A.1	PI-WH-DC	Truck/train	1	Avoidance	Time	7.5	33 436	67.867
2.R.1	PI-WH-DC	Truck/train	1	Risk taking	Time	7.9	34 741	69.614

In total:
8 disruption profiles*2 disruptions protocol*2 optimisation criteria scenarios = 32 scenarios + 3 (reference without disruptions) = 35 scenarios

Result analysis

Total logistics cost



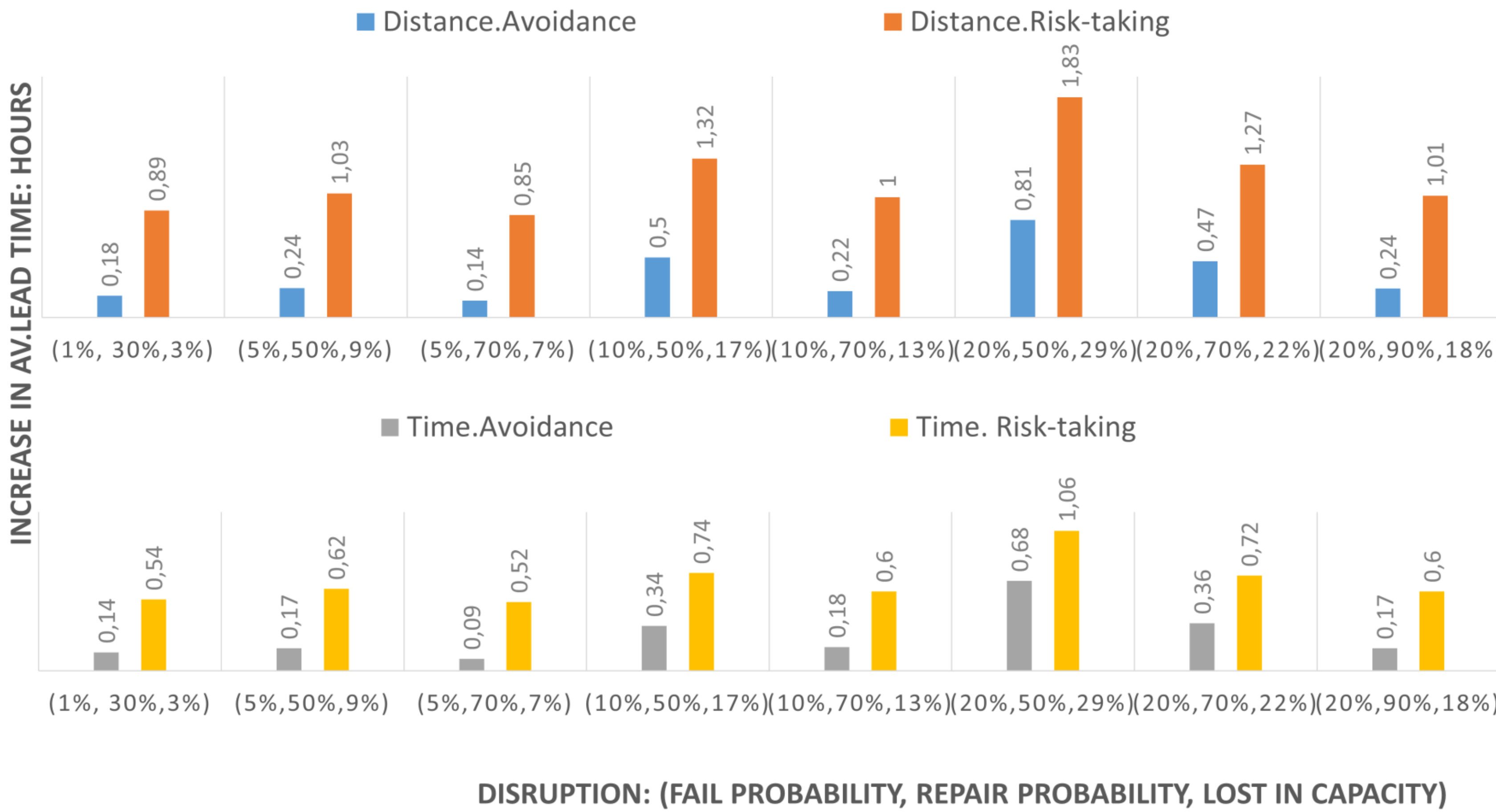
Lost in capacity of PI: 3%~29% vs Augmentation in cost: 0%~4%

Long rare disruptions: Avoidance

Frequent disruptions: Risk-taking

Result analysis

Average lead time

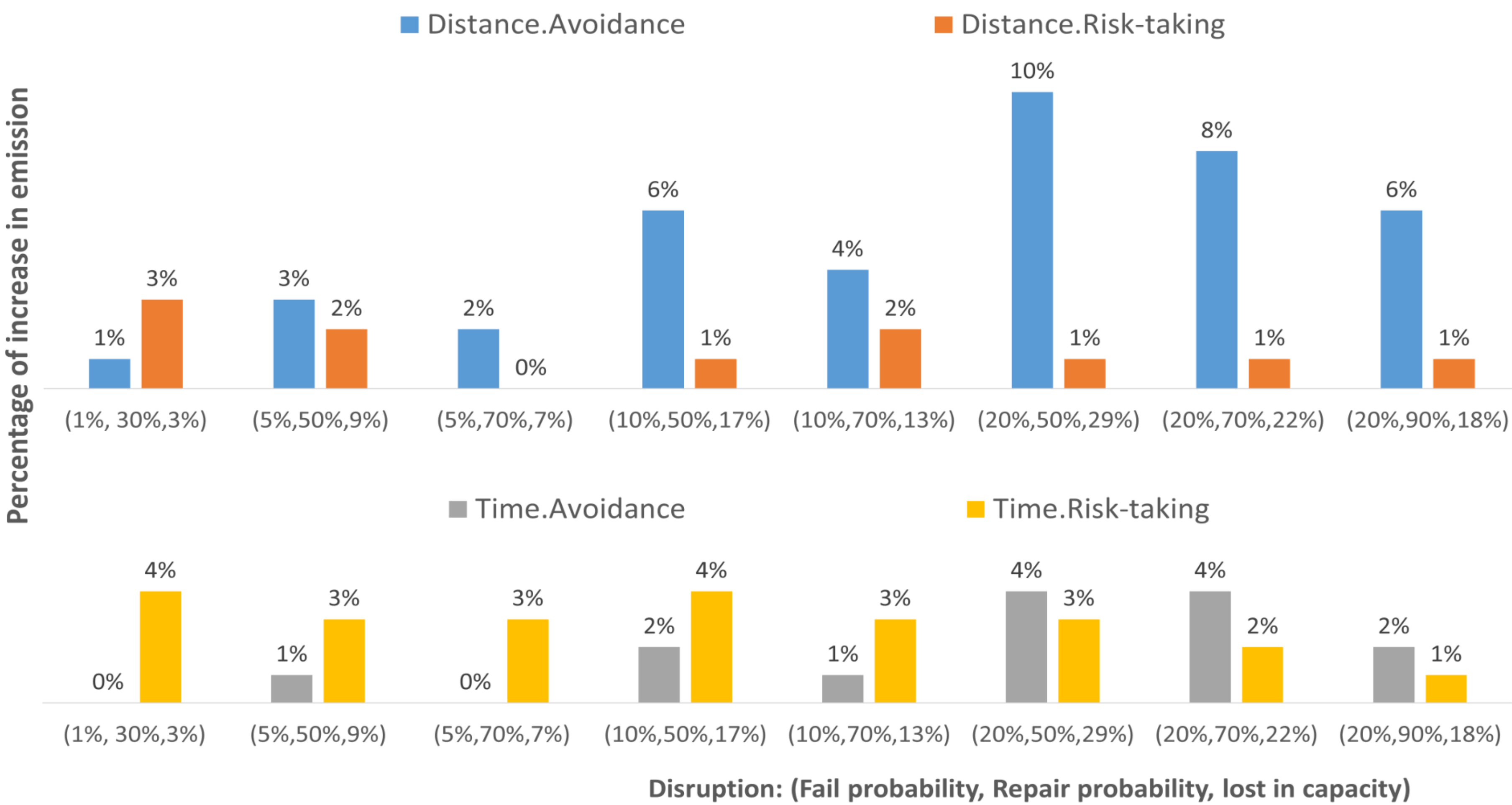


Maximum: 1,83/8h in augmentation in average lead time

Avoidance outperforms Risk-taking

Result analysis

Total transport emission:



Lost in capacity of PI: 3%~29% vs Augmentation in emission: 1%~10%

Distance: Risk-taking

Time: Risk-taking for frequent disruptions, Avoidance for rare long disruptions

Conclusions and perspectives

Conclusions:

1) Doesn't exist one optimal protocol;
2) Total logistics cost: maximum 4% vs 29% lost in capacity of PI;
3) Lead times: maximum 1,83/8 hours for 29% lost in capacity of PI;
4) Emission: maximum 10% for 29% lost in capacity of PI.

Criteria	Disruptions Profile								KPIs
	Rare Very long	Rare Long	Rare Mi-long	Less frequent Long	Less frequent Mi-long	Frequent Long	Frequent Mi-long	Frequent Short	
Distance	Avoidance	Avoidance	Avoidance	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Cost
	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Lead time
	Avoidance	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Risk-taking	Emission
Time	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Risk-taking	Risk-taking	Risk-taking	Cost
	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Lead time
	Avoidance	Avoidance	Avoidance	Avoidance	Avoidance	Risk-taking	Risk-taking	Risk-taking	Emission

Physical Internet is a resilient network to disruptions at hubs.

Conclusions and perspectives

Perspectives:

- Categorization of disruptions
- Shipper strategies, i.e. inventory management

Thank you for your attention!