Freight transportation mechanisms in the physical Internet

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Research questions

- How can actors, including logistics providers, could understand PI and put in put into practice?

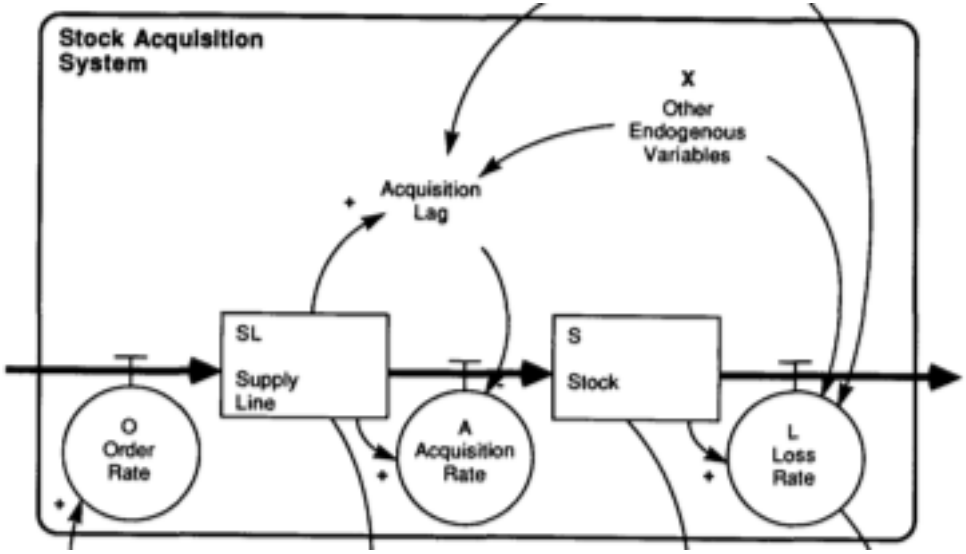
- How do collaborative exchange mechanisms could work?
  - What will be the impact on the overall efficiency of the system?
  - What will be the impact on the behavior of the actors

A tangible simulation and closer to reality by a board game (Gamification)

Objectives

Experimental platform

- Put actors in "Serious Game" situation
- Education and awareness
- Evaluate the performance of the PI approach under proposed mechanisms and rules



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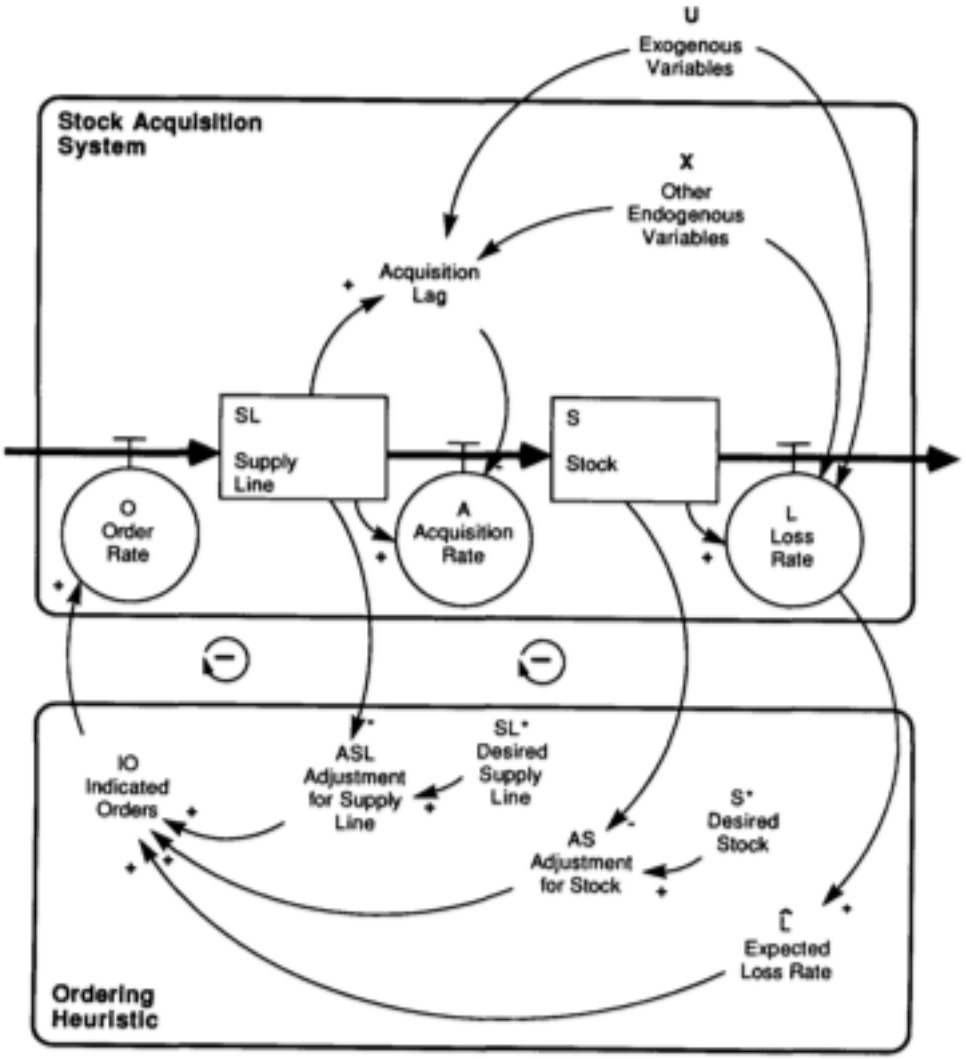
Objectives

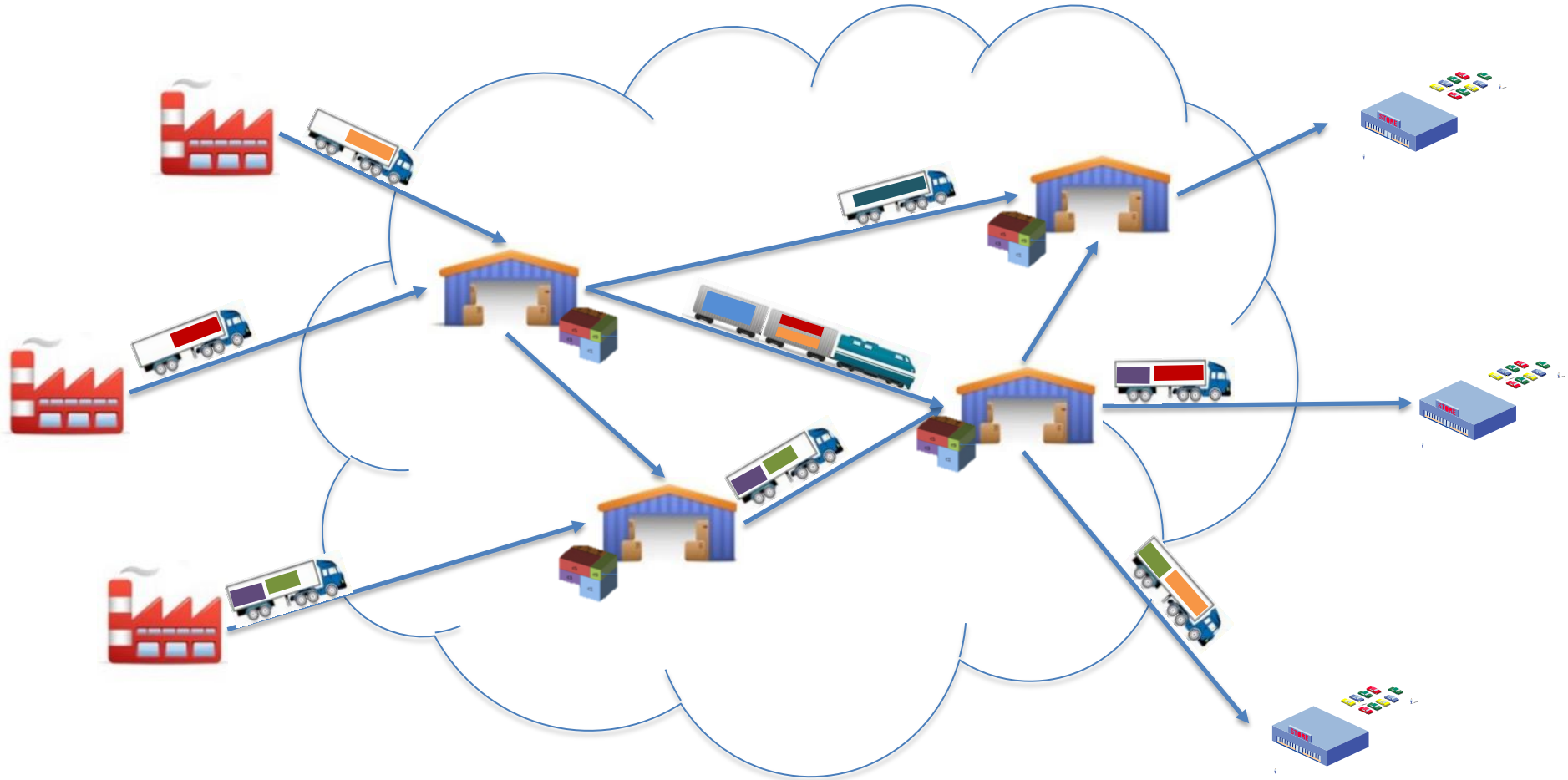
Experimental platform

- Determine the optimal allocation of resources that minimizes the overall cost of the market by taking into account the interest of each actor

- Analyze actors' behaviors according to different situations



As a part of the physical internet

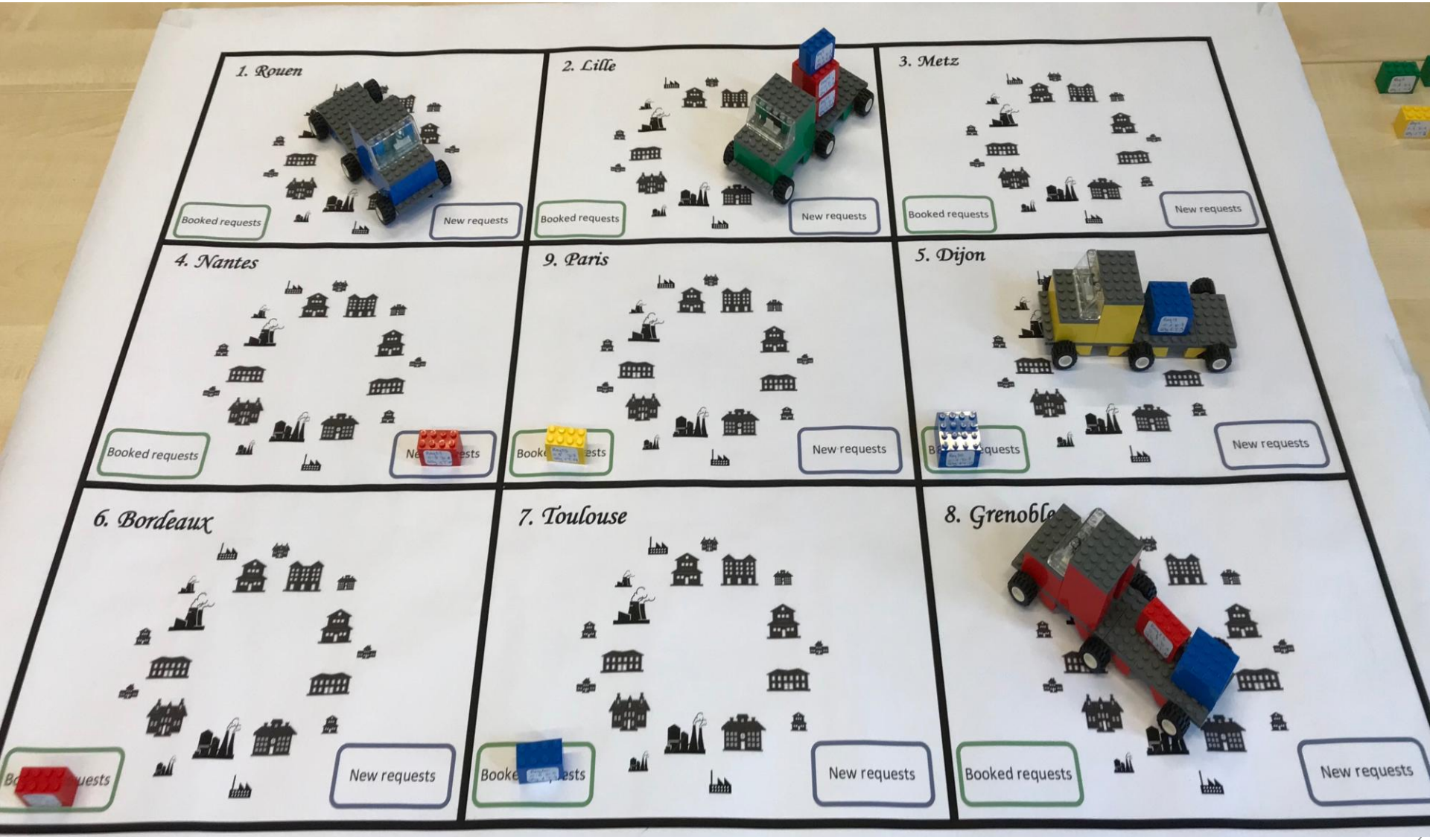


Providers

Physical internet network

Clients

The freight transport game



The game: Inputs

Requests

- Each round, new requests are generated randomly
  - Origin: randomly generated from 1 to 9
  - Destination: randomly generated from 1 to 9
  - Quantity: randomly generated from 1 to 2 units
  - Lead time: to be calculated from the delivery date T

Request 1:
O: 1 D:3
Qty: 1 T: 8

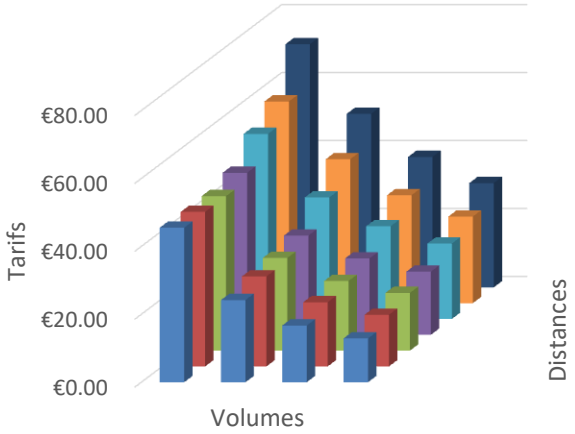
- Delivery date = the round when the request is to be delivered (not to be exceeded otherwise pay the penalty)

- Lead time = Delivery date - Current round

The game: Inputs

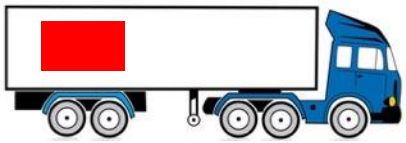
○ Several possible price structures or strategies

- **Prices depend on distance traveled**
- **Prices depend on volumes**
- Tarif : small volume more expensive
- Marginal cost : last volume more expensive
- Allocation to the best player



Truck 1

Truck 2



Tarif2 > Tarif 1

Methodology

○ Experimental platform

Analysis of the performance of the PI approach

	Current market	PI approach
Optimal solution	➢ No reallocation ➢ Computer optimization ➢ Proposed Reference Rate Structure	➢ Reallocation is possible ➢ Computer optimization ➢ Proposed Reference Rate Structure
Solution with players	➢ No reallocation ➢ Players playing the game ➢ Players offer their own rates	➢ Reallocation is possible ➢ Players playing the game ➢ Players offer their own rates

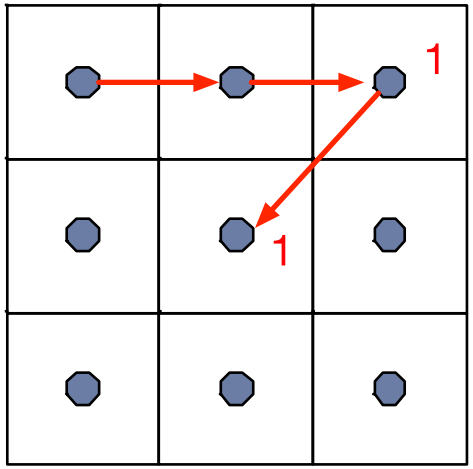
Study the performance of the players comparing to the optimal solution

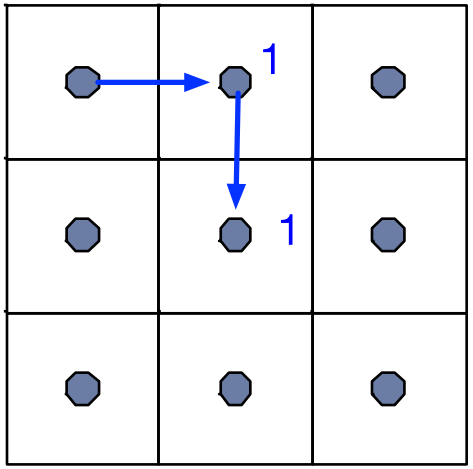
Analysis of player behavior with new mechanisms

What is reallocation?

Without

5+3 u.d



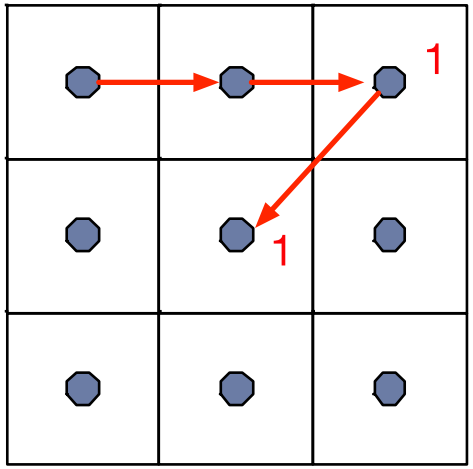


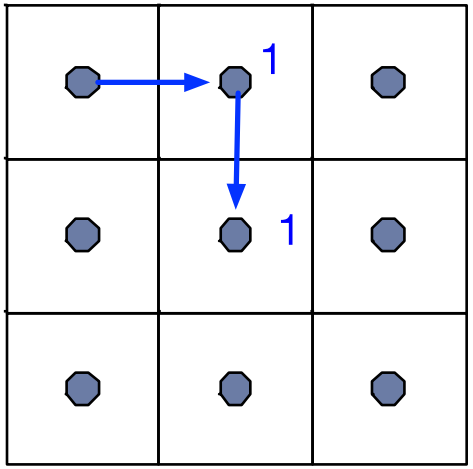
2 transport requests for each

What is reallocation?

Without

5+3 u.d

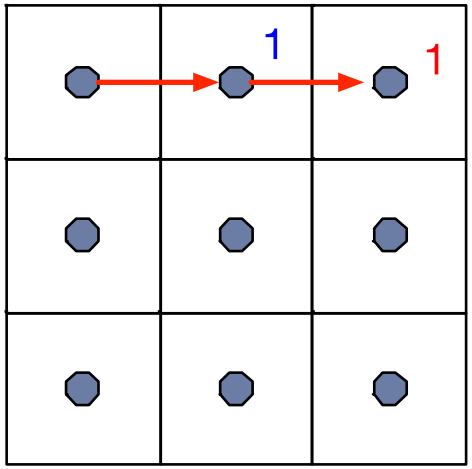


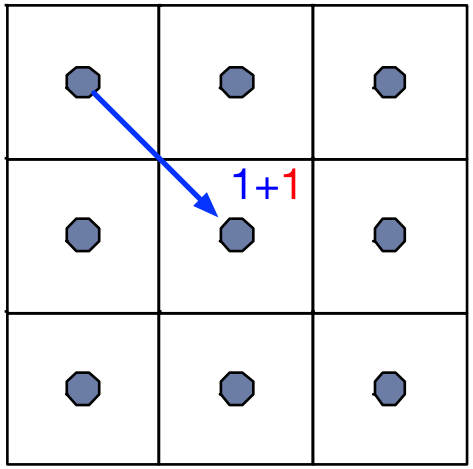


2 transport requests for each

With

3+2 u.d

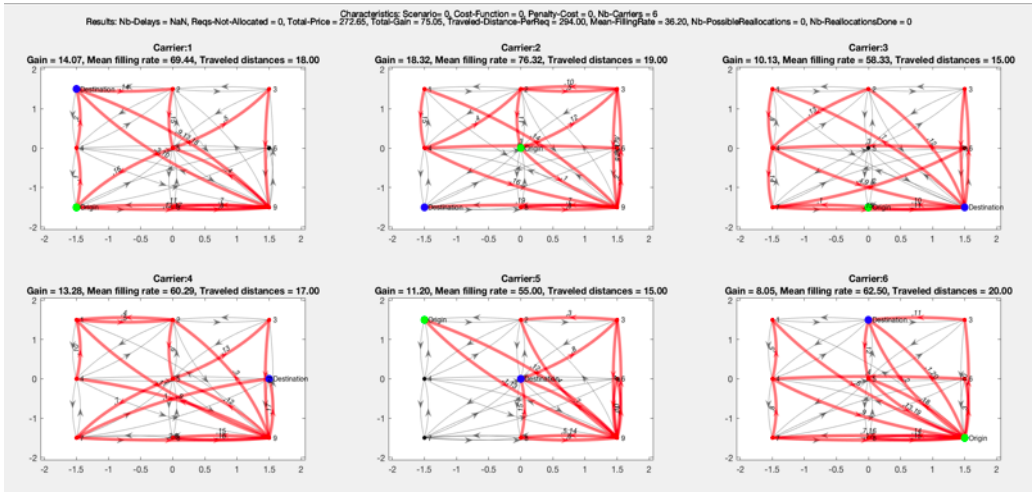


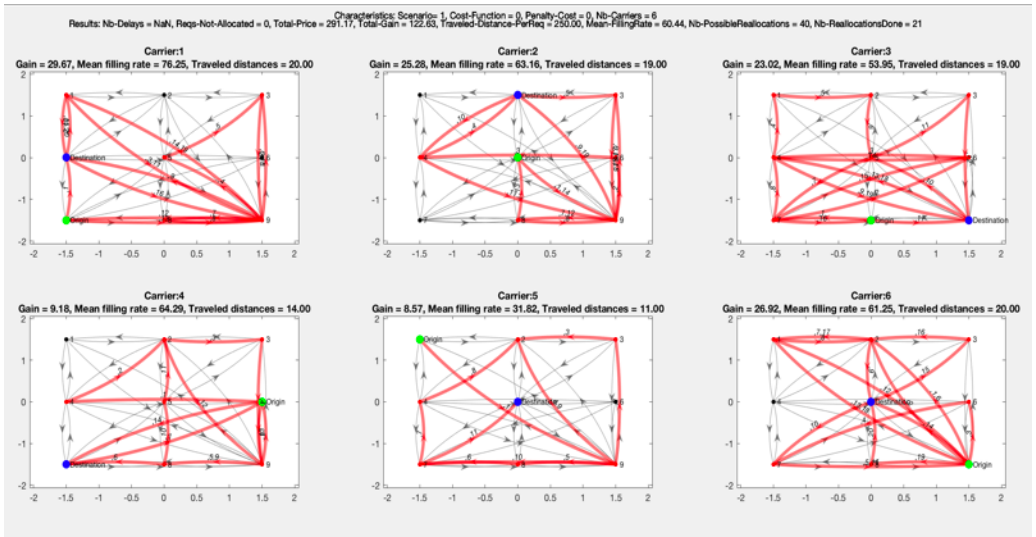


2 transport requests for each but reallocated

Results from optimization

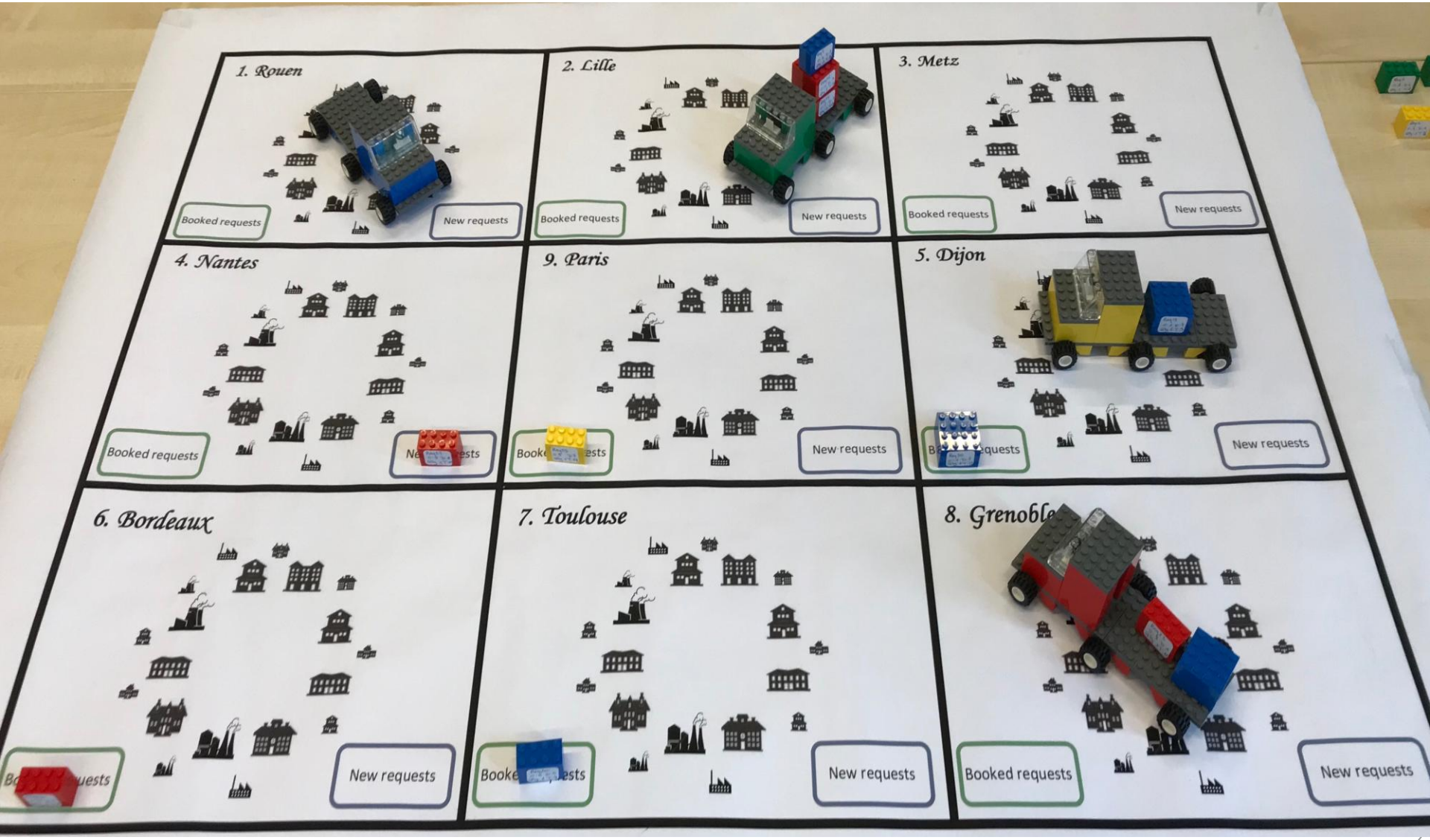
The optimal allocation for 6 carriers





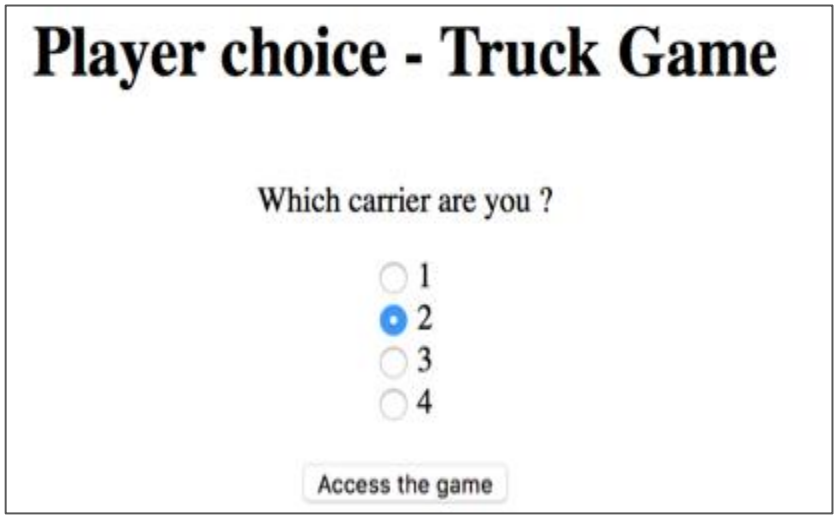
- Total cost
- Total gain for each carriers
- Routes operated by carriers
- Distances traveled by each carrier
- Fill rate of each carrier
- Gains by carriers
- Potential of reallocation

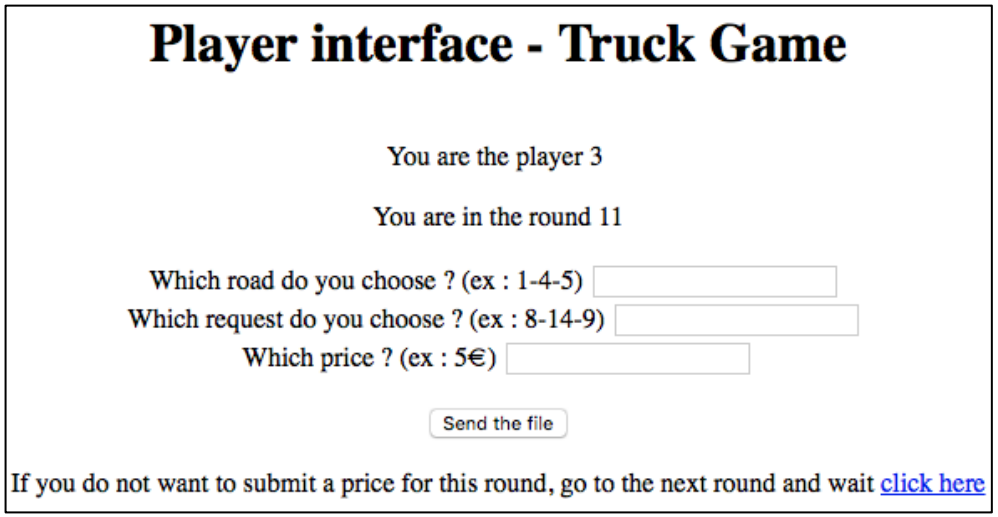
Or the game

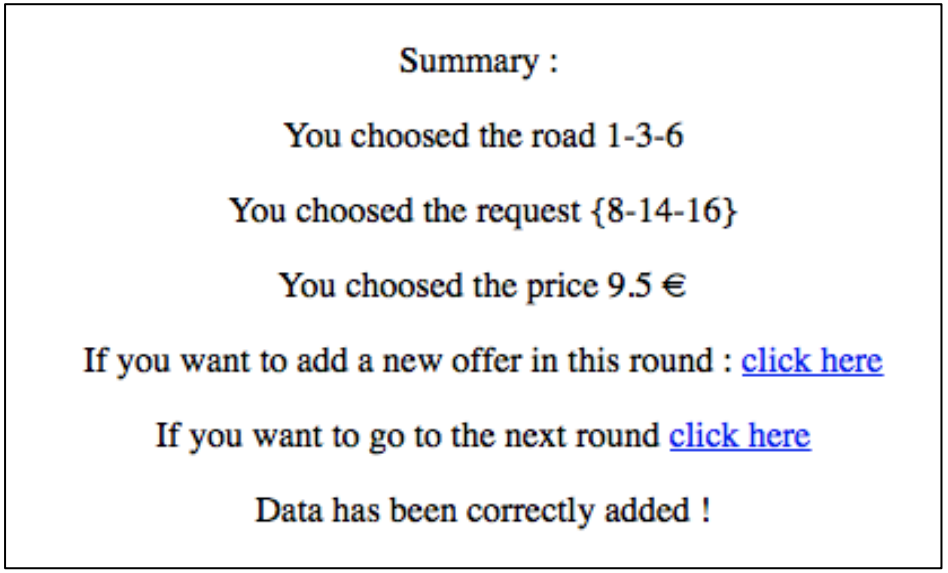

1. Rouen
Booked requests
New requests
2. Lille
Booked requests
New requests
3. Metz
Booked requests
New requests
4. Nantes
Booked requests
9. Paris
New requests
5. Dijon
New requests
6. Bordeaux
New requests
7. Toulouse
New requests
8. Grenoble
Booked requests
New requests

The game interface

Interface web – 4 players







The mechanism behind the game

Resource Allocation by combinatorial auction

$$min \sum_{m \in M} \sum_{rt \in Rt_h} \sum_{RB_k \subseteq RB_h; RB_k \subseteq RB_{h,rt}} P^m_{rt,RB_k} y^m_{rt,RB_k} \quad 5.1$$

Minimize the total cost for all bundles

Subject to

$$\sum_{rt \in Rt_h} \sum_{RB_k \subseteq RB_{h,rt}} y^m_{rt,RB_k} \leq 1, \quad \forall m \in M, \quad 5.2$$

Each carrier can have at most one bundle

$$\sum_{m \in M} \sum_{rt \in Rt_h} \sum_{RB_k \subseteq RB_{h,rt};\, r_i \in RB_k} y^m_{rt,RB_k} = 1, \quad \forall r_i \in R_h \quad 5.3$$

All requests are allocated

$$\sum_{m \in M} \sum_{rt \in Rt_h} \sum_{RB_k \subseteq RB_{h,rt};\, r_i \in RB_k} RP^{mt}_{rt,RB_k} y^{mt}_{rt,RB_k} \leq RC'_{tr_i} \quad \forall tr_i \in Rtr_h \quad 5.4$$

Request Reallocation

$$y^m_{rt,RB_k} \in \{0,1\}, \quad \forall h \in N, \forall m \in M, \forall rt \in Rt_h, \forall RB_k \subseteq RB_h \quad 5.5$$

Binary variables

Results

○ Performance of the PI approach

Performance criteria	Scenario 0 : current market	Scenario 1: PI approach
Traveled distance	294 distance unit	250 distance unit
Carrier's Filling rate	36.20%	60.44%
Total gain of carriers	75.05 price unit	122.63 price unit

→ The PI scenario outperforms the current situation in terms of market efficiency, minimizing overall transport cost and optimizing resource allocation

Results

Next steps

	Current market	PI approach
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Solution with players	➢ No reallocation ➢ Players playing the game ➢ Players offer their own rates	➢ Reallocation is possible ➢ Players playing the game ➢ Players offer their own rates

Study the performance of the players comparing to the optimal solution

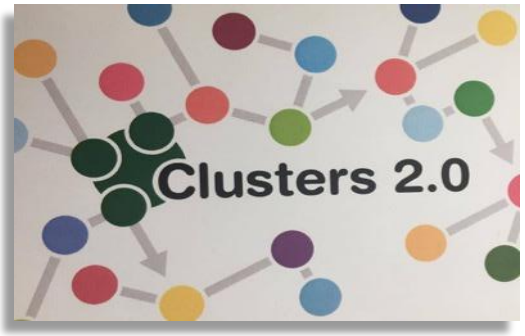
Analysis of player behavior with new mechanisms

Play sessions with professionals and students

- actors' behaviors
  - Empirical studies in progress with the logistics team and with industrial partners

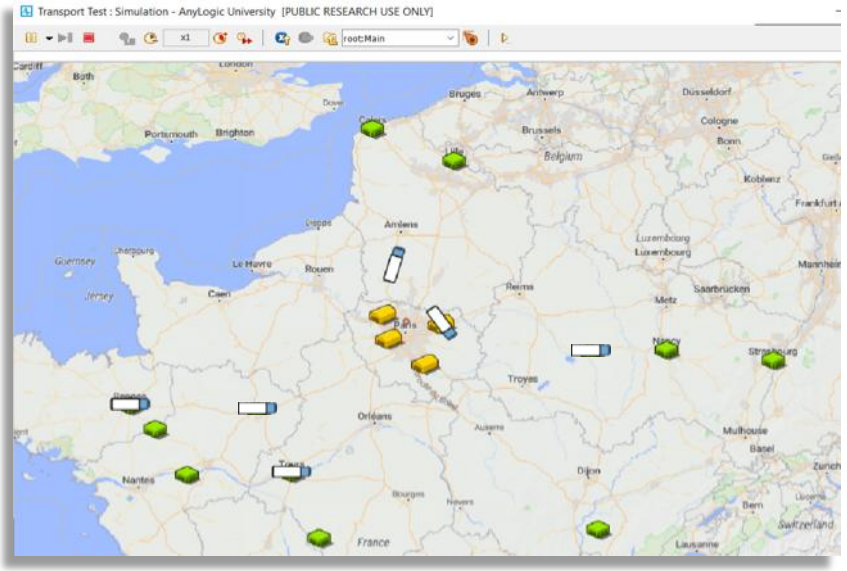
Perspectives

- Develop collaborative mechanisms and examine them through the plays
- Empirical study on the behavior of actors (players)
- Applying results and exploring conditions for implementing mechanisms
- Two fields of application
- Will be packaged soon



Project H2020

Project PIA



Questions

Thank you for your attention