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From the Digital Internet to the Physical Internet: A conceptual framework with a simple network model

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What is the Physical Internet (PI)?

The PI was initiated to…

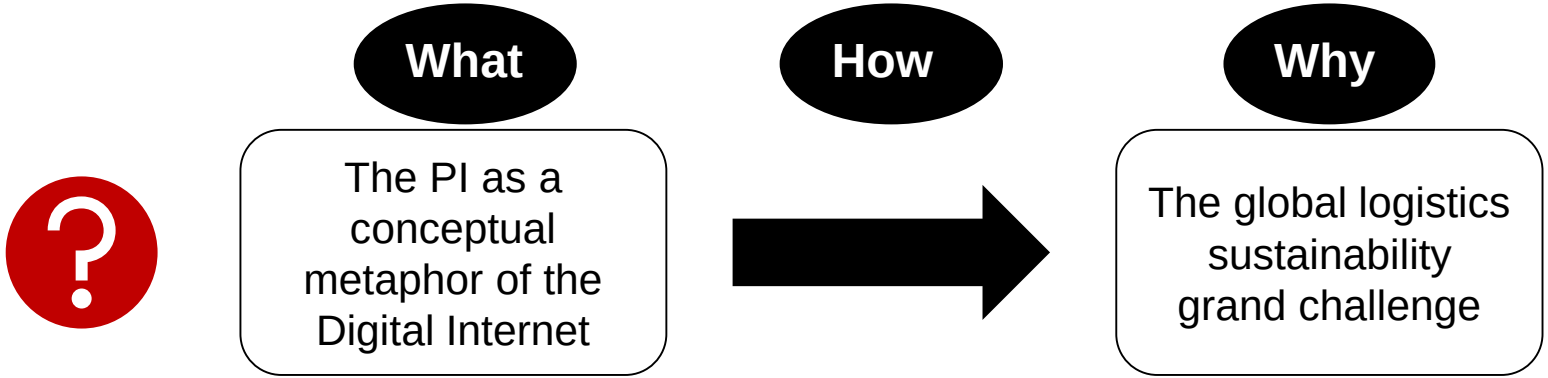
The global logistics sustainability grand challenge[1]

Transport air, congestion in cities, pollutions, new IT technologies are not fully utilized, etc.

- The Information highway gets physical, the future of logistics (Mervis et al. 2014)
- ALICE, Horizontal 2020

[1] Montreuil, B. 2011. “Toward a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge.” *Logistics Research* 3 (2–3): 71–87.

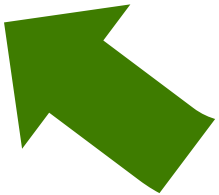
What is missing in the PI research



- How will PI contribute to improve sustainability? (Sternberg and Norrman, 2017)
- The implementation of PI remains a challenge (Cimon, 2014; Treiblmaier et al., 2016)

Our contribution

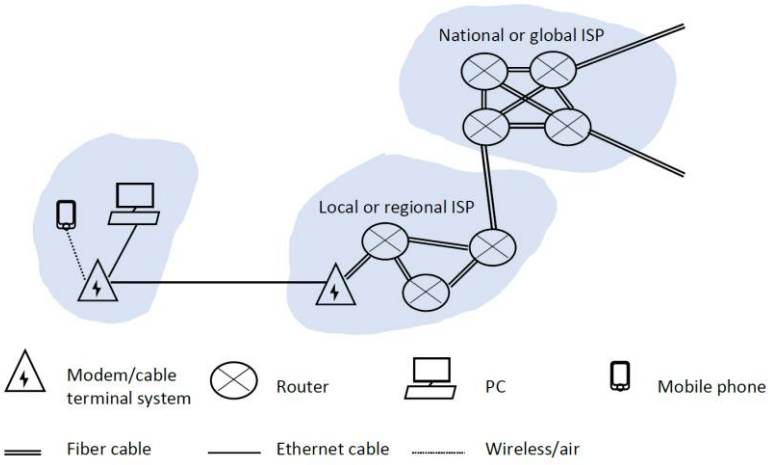
A simple network model as a first step to support the implementation of the PI



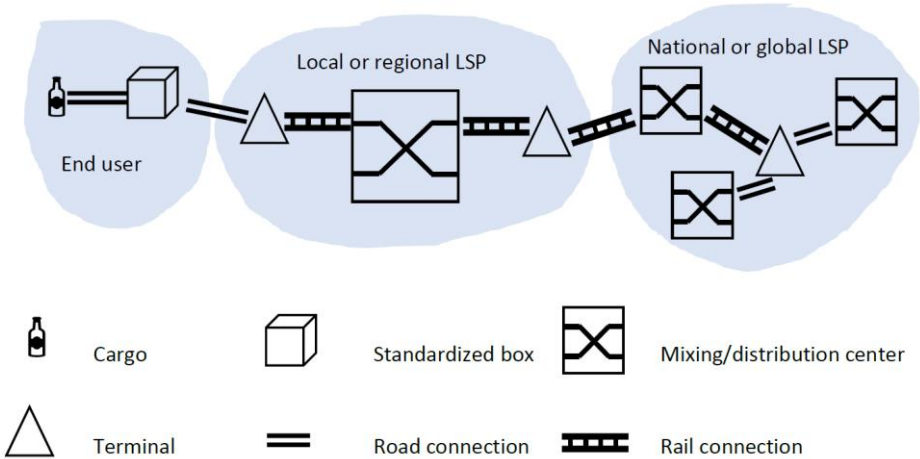
- A study of the PI on the basis of the Digital Internet (DI)
- Similarities and differences between the DI and the PI
- A simple network model of the PI
- Analysis and simple heuristic of the model
- Use the model to support PI implementation: a simple case study

Similarities in the network structure

The Digital Internet



The Physical Internet

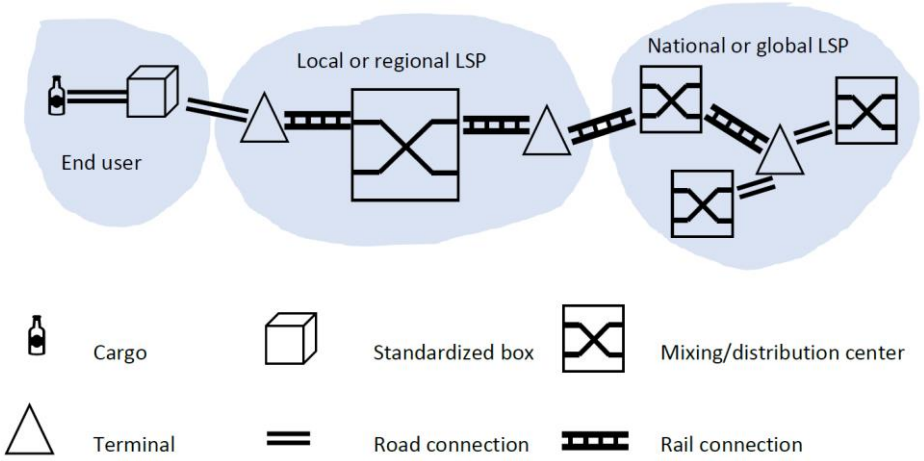


Differences between the DI and the PI

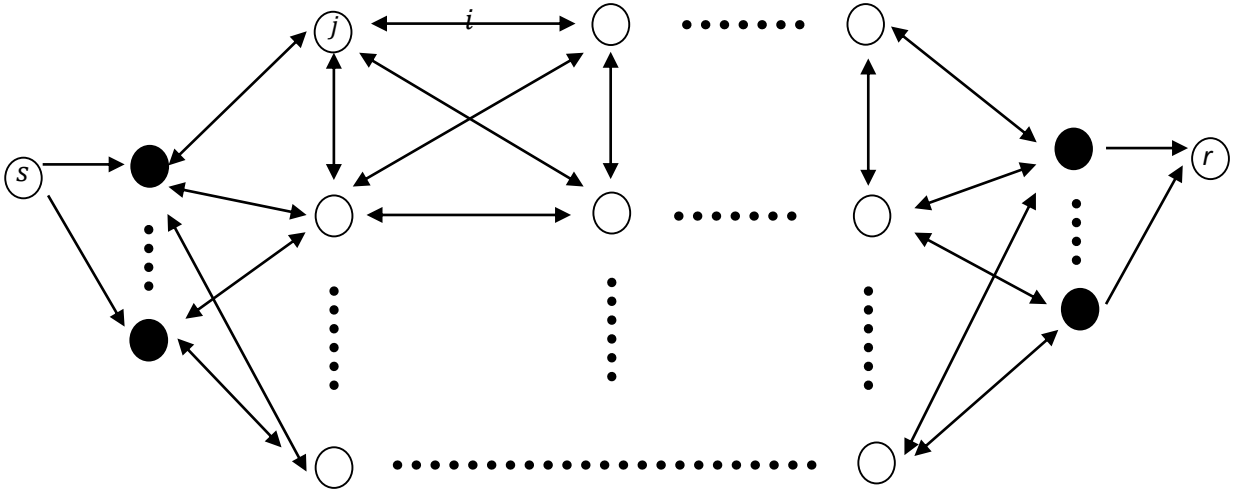
The Digital Internet	The Physical Internet
• Digital signals (0/1) in standardized packets	• Physical objects in standardized boxes
• Near-light transmission speed • Trivial transmission cost	• Lead time of transport modes • Substantial transportation cost
• *The reachability problem*: how to transmit from A to B	• *The reachability problem*: how to ship from A to B • ***The optimality problem***: how to optimize cost, lead time, etc. dynamically

A PI model should incorporate…

- A huge number of participants
- A network with a topology
- Each participant has its weight in cost, lead time, etc.
- Dynamic weights and topology
- Reachability and optimality problems can be analyzed

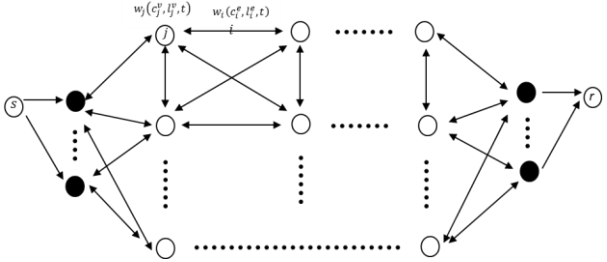


The simple network model of the PI

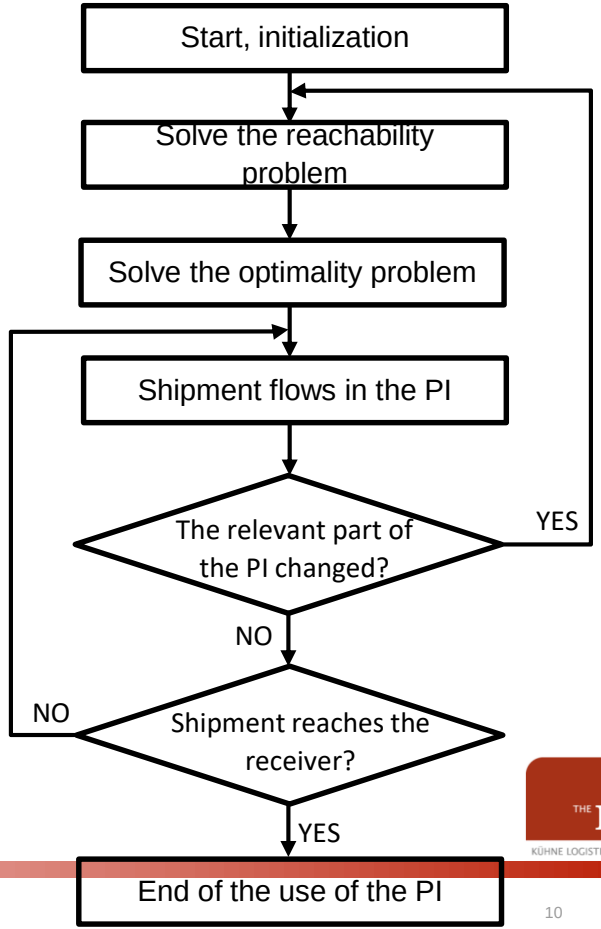


- A graph with nodes (logistics centers) and arcs (transport connections)
- Each node/arc is associated with a weight vector *w.* The elements of the vectors represent the cost, lead time, timing, etc.
- Cost/lead time minimization from *s* to *r*, subject to (dynamic) constraints and topology

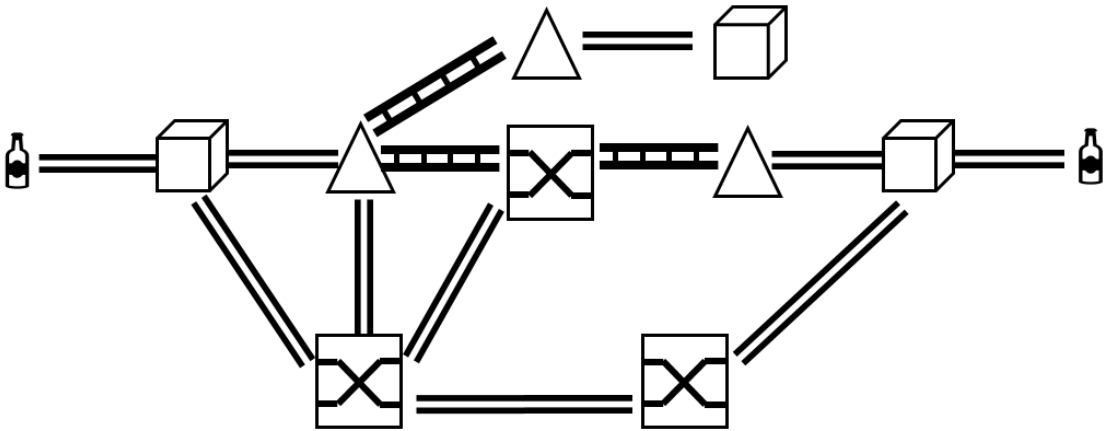
Model analysis and solution

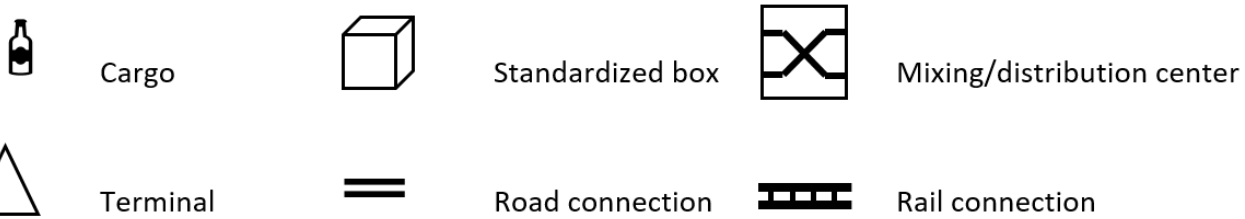


- Only to minimize total logistics cost: the classical travelling salesman problem (TSP)
- Only to consider delays in the network flow due to capacity constraints: the classical traffic assignment problems (TAP)
- To combine both TSP and TAP in a time-dependent network, which is larger than any transportation problems studied so far?
- Our first heuristic

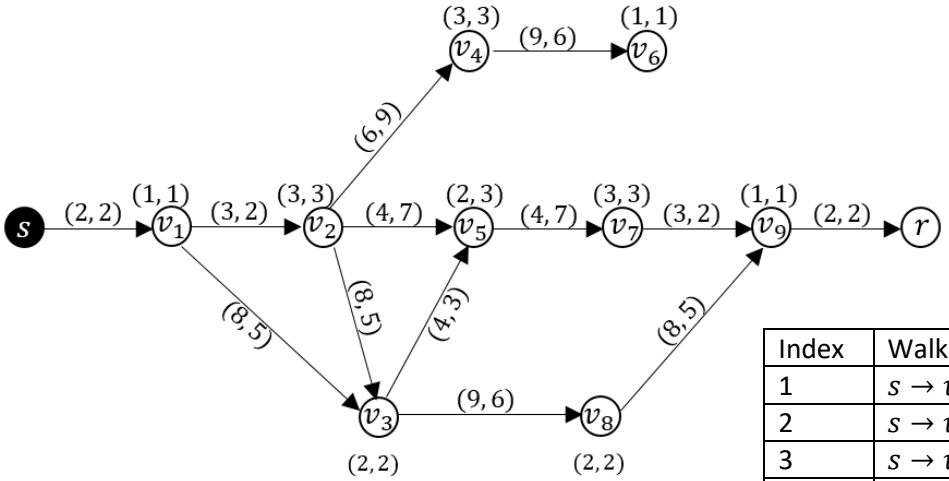


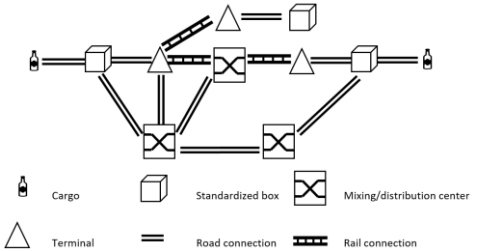
A simple case study





Our PI model

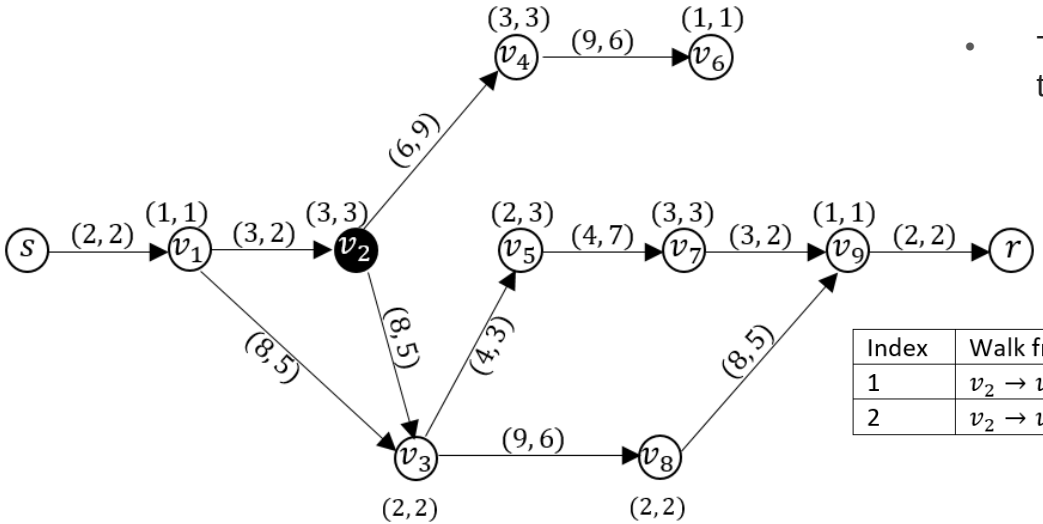




Index	Walk from vertex s to vertex r	Total cost	Total lead time
1	$s \to v_1 \to v_2 \to v_3 \to v_5 \to v_7 \to v_9 \to r$	38	36
2	$s \to v_1 \to v_2 \to v_3 \to v_8 \to v_9 \to r$	41	31
3	$s \to v_1 \to v_2 \to v_5 \to v_7 \to v_9 \to r$	23*	33
4	$s \to v_1 \to v_3 \to v_5 \to v_7 \to v_9 \to r$	32	31
5	$s \to v_1 \to v_3 \to v_8 \to v_9 \to r$	35	26*

- Walk 3 is the current cost-minimization route
- Walk 5 is the current lead-time-minimization route

After a change of the PI structure



- The connection between v_2 and v_5 is broken when the shipment reaches v_2

Index	Walk from v_2 to r	Total cost	Total lead time
1	$v_2 \rightarrow v_3 \rightarrow v_5 \rightarrow v_7 \rightarrow v_9 \rightarrow r$	38*	36
2	$v_2 \rightarrow v_3 \rightarrow v_8 \rightarrow v_9 \rightarrow r$	41	31*

- Walk 1 is the current cost-minimization route
- Walk 2 is the current lead-time-minimization route

Summary

- A model to support PI implementation
- Understand the Physical Internet from the Digital Internet
  - Reachability problem
  - Optimality problem
- A simple PI model
  - Graph theory
  - Solution heuristics
- A simple case study

6th International EurOMA, March, 2019 Gothenburg, Sweden

- Sustainable Operations and Supply Chain Management
- Abstract submission deadline: 9/Nov/2018

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