The Physical Internet

Toward Efficient, Sustainable, Interconnected Logistics Networks and Supply Chains

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Presentation Content

• Global Logistics Sustainability Grand Challenge
• Physical Internet Vision
• Efficient, Sustainable, Interconnected Logistics Networks and Supply Chains
• Physical Internet Potential Assessment from Large Scale Projects in America and Europe
• Ongoing and In-Preparation Projects
• Conclusion
At face value, logistics seems to be doing great!

Supply Chain Logistics is the backbone sustaining

Our lifestyle  E-Commerce  World Trade

Adapted from an original slide concept by Professor Russ Meller, CELDi, U. of Arkansas
Yet we have to face a harsh fact

Logistics inefficiency and unsustainability claim

The way physical objects are moved, stored, realized, supplied and used throughout the world is economically, environmentally and socially inefficient and unsustainable.
Why do we need to change?

Logistics inefficiency and unsustainability

**ECONOMIC**

Logistics: 5-15% burden on GDP of most countries

Worldwide logistics costs grow faster than world trade

**ENVIRONMENT**

One of the heaviest greenhouse gas generators, energy consumers, polluters and materials wasters

Growing negative contribution while nations’ goals aims for heavy reductions

**SOCIAL**

Lack of fast, reliable and affordable accessibility and mobility of physical objects for the vast majority of the world’s population

Too often precarious logistic work conditions

![Graph showing CO2 emissions and t.km over years from 1990 to 2010]
Inefficiency & Unsustainability Symptoms

We are shipping air and packaging
Average of 60% weight-volume capacity at departure

Empty travel: norm rather than exception

25% of road travel

Truckers have become the modern cowboys
Often leaving home for long durations

High turnover rate
Inefficiency & Unsustainability Symptoms

Products mostly sit idle, stored where unneeded, yet so often unavailable fast where needed

Poorly / badly used production and storage facilities

So many products are never sold, never used

Products do not reach those who need them the most
Inefficiency & Unsustainability Symptoms

Products unnecessarily crisscross the world
City logistics is a nightmare
Multimodal transport too constraining
Supply chains are unsecure and fragile
Automation & technology hard to justify
Innovation is strangled
The Global Logistics Sustainability Grand Challenge

Design a system to move, store, realize, supply and use physical objects throughout the world in a manner that is economically, environmentally and socially efficient and sustainable.

Eliciting the Grand Challenge Toward Global Logistics Efficiency and Sustainability

**Environmental goal**
Sustainably reduce by an order of magnitude the logistics-induced global greenhouse gas emission, energy consumption, pollution, traffic & materials waste

**Economic goal**
Sustainably reduce by an order of magnitude the global economic burden of logistics while unlocking huge gains in business productivity

**Societal goal**
Sustainably and significantly increase the quality of life of the logistics workers and the world’s population by improving the timely accessibility and mobility of physical objects
Meeting the IT Grand Challenge

Building Upon the Information Superhighway Metaphor

Before: millions of unconnected computers
After: millions of connected servers and computers to form the “Information Superhighway”

Key Enabler: transmission of formatted data packets through heterogeneous equipment respecting the TCP/IP protocol

Result: The Digital Internet - an open, distributed networked infrastructure
The Physical Internet Initiative
Using the Digital Internet as a Metaphor for the Physical World

Even though there are fundamental differences between the physical world and the information world, the Physical Internet initiative aims to exploit the Internet metaphor so as to propose a vision for a sustainable and progressively deployable breakthrough solution to global problems associated with the way we move, store, realize, supply and use physical objects all around the world.

Montreuil B. (2011) Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge, Logistics Research, currently available as online publication, 2011-02-12, http://www.springerlink.com/content/g362448hw8586774/fulltext.pdf
Simplified Mental Image of the Physical Internet

- Open market for goods transportation (eBay-style)
- Handles only “black box” modular containers
- Open and shared transportation and distribution networks
- Vast community of users
- Supplier certification and ratings-by-users to drive logistics performance
- Continuous tracking & monitoring of containers, assets and services

Seamless modular container consolidation in the Physical Internet
B. Montreuil & C. Thivierge, 2011

Adapted from a contribution of Professor Russ Meller from CELDi, U. of Arkansas
The Physical Internet (PI, π)

The Physical Internet is an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols.

The PI aims to enable an efficient, sustainable, adaptable and resilient Logistics Web.

Evolution of Supply Chains & Logistics

**Atomistic**
- Fragmentation, Solo Operations
- Long leadtime, big lots, large inventory

**Integrated**
- EDI, Just-In-Time, ECR, Lean
- Dedicated & Centralized DCs & Factories
- End-to-End Supply Chain

**Collaborative**
- Horizontal & Vertical Collaboration with SC partners
- Economies of Scale/Scope, Green

**Interconnected**
- Physical Internet, Logistics Web
- Open hubs, DCs & fabs, Co-operation Platforms
- Efficiency, Sustainability, Resilience, Agility

Timeline

Benoit Montrueil & Jean-Claude Dufour, Laval University
Physical Internet Induced Innovation

- Cultural Innovation
- Technological Innovation
- Business Model Innovation
- Infrastructural Innovation

π-Enabling Innovation

π-Enabled Innovation
Encapsulating goods in $\pi$-containers

- Light
- Green materials
- Minimal off-service footprint
- Various grades
- Conditioning capabilities

Products ever better designed for encapsulation

Original drawing by Eric Ballot, Mines ParisTech, 2011-06-27, adapted by Benoit Montreuil
World standard modular dimensions and fixtures
From cargo container size to pallet size, down to tiny box size

Conceptual design by Benoit Montreuil and Marie-Anne Côté
CIRRELT, Université Laval, Québec, Canada, 2012

Illustrative potential modular dimensions

The illustrated \( \pi \)-container design has a strictly conceptual and functional: it has no prescriptive technical design and engineering intent.
π-Containers Designed for Logistics

Easy to handle, store, transport, load, unload, panel, snap, interlock, construct, dismantle, compose and decompose

Conceptual design by Benoît Montreuil and Marie-Anne Côté
CIRRELIT, Université Laval, Québec, Canada, 2012

The illustrated π-container design has a strictly conceptual and functional: it has no prescriptive technical design and engineering intent
Evolve from material to $\pi$-container transport, handling & storage means and systems

$\pi$-containers moving and storage means and systems, with innovative technologies and processes exploiting the characteristics of $\pi$-containers to enable their fast, cheap, easy and reliable input, storage, composing, decomposing, monitoring, protection and output through smart, sustainable and seamless automation and human handling.

New generation of logistics facilities
Seamless, fast, cheap, safe, reliable, distributed, multimodal transport and deployment of $\pi$-containers across the Physical Internet

The Physical Internet: the same conceptual framework at any scale

Intra-center Inter-processor Network
Intra-Facility Inter-Center Network
Intra-Site Inter-Facilities Network

Intra-City Inter-Site Network
Intra-Continental Inter-City, Inter-State/Province Network
Inter-Continental Worldwide Network
Enabling a Logistics Web

Set of openly interconnected physical, digital, human, organizational and social agents and networks aiming to serve efficiently and sustainably the logistics needs of people, organizations, territories and society

Realization Web
Realizing products
*Interconnected open production, personalising & retrofit centers*

Distribution Web
Deploying, storing products
*Interconnected open warehouses & distribution centers*

Mobility Web
Moving goods & people
*Interconnected open unimodal & multimodal infrastructures, movers, hubs and transits*

Supply Web
Supplying goods
*Interconnected open suppliers and subcontractors*

Service Web
Enabling and sharing access and usage of services rendered by goods & people
*Interconnected open users and service providers*
Transporting a trailer from Québec City to Los Angeles

Distance travelled one-way: 5030 km
Drivers: 1
Trucks: 1
Trailer: 1
One-way driving time (h): 48
Return driving time (h): 48+
Total time at transit points (h): 0
Total trailer trip time from Quebec to LA (h): 120
Total trailer trip time from LA to Quebec (h): 120+
Total trailer round trip time (h): 240+
Average driving time per driver (h): 96+
Average trip time per driver (h): 240+ 6,5

Enabling an open global mobility web
From point-to-point or hub-and-spoke transport to distributed multimodal transport
Enabling an open global mobility web
From point-to-point to distributed transport of full-load trailers

In order to be efficient and sustainable, the simple full-load truck-trailer focused mobility web should be supported by a PI backbone network of highly efficient and sustainable transit centers.

Road-Based Transit Center Alternative 1
Enabling and achieving the transfer of $\pi$-carriers from their inbound $\pi$-vehicles to their outbound $\pi$-vehicles.
Enabling an open global mobility web
From point-to-point hub-and-spoke transport to distributed multimodal transport

Set of modular containers to be shipped

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<th>Dimensions</th>
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Containers loaded on a single trailer at the source
Enabling an open global mobility web

From point-to-point or hub-and-spoke transport to distributed multimodal transport

Multi-segment routes taken by the modular containers from a single shipment out of the source through the open Mobility Web to their individual destination.

Only locations, hubs and roadways pertinent to the shipment have been drawn: there are many more in the Mobility Web.
Illustrating Current Logistics Systems
A small two-retailer two-manufacturer case

**Current Conceptual Networks**

Adapted from: Hakimi D., B. Montreuil & E. Ballot (2012), Simulating a Physical Internet Enabled Logistics Web: the Case of Mass Distribution in France, ISERC 2012, 2012/5/19-23
The Impact of Exploiting a Mobility Web
Here limited to unimodal road transport

**Travelled distance:** -27%
**Fuel Consumption:** -19%
**Average delivery time:** +2%
**Maximum delivery time:** -36%
Simplified Distribution Networks of Four European Retailers
European Networks of Seven Producers
Overlaid Supply Chain Networks of Retailers and Producers
Illustrative Open Hub Backbone Network of an European Mobility Web
Exploiting a Mobility Web for an Illustrative Shipment
Away from dedicated distribution networks towards exploiting a Distribution Web

There are 535,000 warehousing & distribution centers in the U.S.A. only

Most of them are used by a single company
Most companies use often a single DC and generally less than 20 DCs

Imagine the potential if each company could deploy its products through an open web including 535,000 open DCs in the USA
Dynamically Deploying Stock Across the Distribution Web for Efficient, Fast & Agile Customer Response

Current private system

Proposed open system

Adapted from: Hakimi D., B. Montreuil & E. Ballot (2012), Simulating a Physical Internet Enabled Logistics Web: the Case of Mass Distribution in France, ISERC 2012, 2012/5/19-23
The Impact of Exploiting a Logistics Web Integrating Mobility and Distribution Webs

Private Logistics Networks

- [Average; Max] Delivery-Time-to-Store
  - -79%; -71%

Mobility Web

- +16%; +15%
- -19%; -27%

Mobility Web + Distribution Web

- -29%; -23%
- -82%; -74%
- -42%; -44%

Fuel; Travel

[Average; Max] Delivery-Time-to-Store

-79%; -71%
Actual Deployment of Retailer Inventory for Spain & Portugal
Deployment of Retail Inventory Exploiting a Distribution Web

- Open hub zone
- Retail market zone
- Airport/Seaport
- Factory
- Land travel link
- Sea travel link

% of current retailer inventory devoted to serving Portugal & Spain deployed at DC

Map background imported from Google Maps

B. Montréal, CIRRELT, Université Laval, 2013/01/31
Dynamically Outsourcing Product Realization to Certified Open Centers across the Realization Web to Enable Efficient & Agile Near Point-of-Use Product Realization

Current realization network centered around an integrated manufacturing & assembly plant

Alternative realization network exploiting realization web for outsourcing assembly

Alternative realization network exploiting realization web for outsourcing manufacturing & assembly
A Supply Web with Myriads of $\pi$-Certified Suppliers, Open & Global Access, Standardized Contracts, Open Monitoring and Supplier Ratings

Multi-tiered,
from raw materials
to final products

Each exploiting
the Mobility,
Distribution & Realization webs
From retail/rental networks feeding isolated clients

To interconnected users exploiting an open Service Web

Getting access as needed to product functionality, from product owners-users and rentals, buying products in lesser percentage

Supported by the other Logistics Web constituents
Towards efficient, sustainable and interconnected urban mobility and city logistics enabled by the Physical Internet

Illustrating current best-practice logistics in a concentric city

Crainic T & B. Montreuil, 2012, City Logistics & Physical Internet
Interconnected Urban Logistics

Exploiting most zone-appropriate \( \pi \)-container transport, handling & storage modes, vehicles, means & facilities

Exploiting existing infrastructures (subway, tramway) and gradually developing innovative interconnected infrastructures

Aiming for gains in economic, environmental and societal efficiency and sustainability

B. Montreuil & T. Crainic, CIRRELT
An American Study in the Consumer Goods Industry Shows That Goods Encapsulation in Modular Containers Saves Space (Without Even Adapting Product Shape to Container Sizes)

**Actual**
- Items in cases 88.9%
- Cases on Pallets 69.5%
- Global 61.7%

**Modular Containers**
- Items in Modular Containers [67.9%, 70%]
- Modular containers on equivalent-pallets 100%
- Global [67.9%, 70%]

Exploiting Mobility Web for the Consumer Goods Industry in France
Road and rail transport seamlessly integrated into the PI backbone network

Simulation based on product distribution flow to Carrefour & Casino in France, from their 100 top suppliers

Preliminary results using existing infrastructures, facilities, demand patterns and service levels

Economical: Up to 26% overall cost saving

Environmental: About 60% reduction of greenhouse gas emissions, by combining road-to-rail modal transfer and more efficient road transport

Conservative Estimation of the Physical Internet Potential in U.S.A.

If 25% of the US supply chain would convert to the Physical Internet Principles for Land-Based Goods Transportation:

- Boosting annual profits by 100B$
- Reducing Road Transport Induced GHG emission by 33%

US consumers would pay less for their goods

Results from a project granted by U.S. National Science Foundation and lead by Professors R. Meller (U. of Arkansas) & K.P. Ellis (Virginia Tech)
European Project on Interconnected Logistics & Physical Internet

• Budget: 4 million € (3 from European FP7)
• Partners: 14, Countries: 10 (including Canada)

• From October 2012 to October 2015
• Current state, vision & roadmap 2030 toward interconnected logistics of fast moving consumer goods (FMCG)
• Define and experiment smaller-than-pallet containers for FMCG supply chain
• Three pilot projects in industry
Sample of companies & organizations active in the Physical Internet Initiative

+ Universities across North America and Europe
  Laval, Mines ParisTech, Arkansas, EPFL, Virginia Tech
  Auburn, Berkeley, Bordeaux, Clemson, Georgia Tech, HEC Genève,
  Poly Montreal, Poznan, UQAM, TU Berlin, TU Graz
Positioning the Physical Internet

World Wide Web (WWW)

Digital Internet
Digital Information Packets

Connecting Physical Objects through WWW

Internet of Things
Smart Networked Objects

Logistics Web

Physical Internet
Smart Physical Packets

Smart Grid
Energy Internet

Energy Packets

Conclusion

Tackling Logistics Sustainability Grand Challenge
A highly scalable co-operative approach based on open universal interconnection

Not a Utopia, not a Big-Bang
Get critical mass by exploiting existing infrastructures and means, then get momentum through large scale adoption & innovation

An Open Research and Innovation Endeavour
Worldwide multi-stakeholder collaboration to making it happen

We are shaping large scale collaborative projects in Canada:
Your help is welcome
Thanks for your attention!

Questions, comments and ideas are welcome anytime!

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