Sustainability and Competitiveness
Is the Physical Internet a Solution?

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School of Industrial & Systems Engineering
Director, Physical Internet Center
Director, Supply Chain & Logistics Institute

International Physical Internet Conference
Graz, Austria
2017/07/04
Defining the Physical Internet

Hyperconnected global logistics system enabling seamless open asset sharing and flow consolidation through standardized encapsulation, modularization, protocols and interfaces

A system is said to be hyperconnected when its components (agents, things, etc.) are intensely interconnected on multiple layers, ultimately anytime, anywhere

Layers interconnecting logistics networks and actors notably include digital, physical, operational, business, legal and interpersonal

Image source: clyderathbone.com

Hyperconnected system definition by B. Montreuil, July 2015
Toward an Hyperconnected Logistics Infrastructure

- Certified Open Logistics Service Providers
- Open Logistics Decisional & Transactional Platforms
- Global Logistics Monitoring System
- Certified Open Logistics Facilities and Ways
- Standard Logistics Protocols
- Containerized Logistics Equipment and Technology
- Unified Set of Standard Modular Logistics Containers

Logistics Infrastructure: Shared assets enabling logistics to support supply chains
The Physical Internet
Transforming the way we deal with physical objects across the world

- **Move**
  - Deliver
  - Handle
  - Transport

- **Deploy**
  - Store
  - Distribute

- **Realize**
  - Make/Assemble/Pack
  - Personalize
  - Recycle

- **Supply**
  - Buy/Sell
  - Provide

- **Design**
  - Conceive
  - Engineer
  - Develop

- **Use**
  - Access
  - Exploit
  - Function

- **Beings & Things**
Physical Internet
Impact on efficiency & sustainability

Enables across-the-board order-of-magnitude Improvement of economic, environmental & societal efficiency & sustainability

Improving the playing field across territories, industries and businesses worldwide
The Physical Internet
Designed as a solution to the Logistics Sustainability Grand Challenge

To improve by an order of magnitude
the economical, environmental and societal
 efficiency and sustainability
of the way physical objects are
moved, deployed, realized, supplied, designed and used

Induced cost reduction
Price reduction
Business opportunity
Economic development opportunity

Reduction of
Greenhouse gas emissions
Energy consumption
Waste
Pollution
Traffic & Congestion

Improved
Quality of life
Goods accessibility
Faster more precise delivery
Novel service capabilities
### Inefficiency & Unsustainability Symptoms Tackled by Physical Internet

**Highlighting Impact of Activity Types**

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Use</th>
<th>Move</th>
<th>Deploy</th>
<th>Realize</th>
<th>Supply</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill rates of transport means (50-60%)</td>
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<tr>
<td>Empty travel (25%)</td>
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<tr>
<td>Excess travel</td>
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<tr>
<td>Break-bulk &amp; crossdock time and cost</td>
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<tr>
<td>Multimodality efficiency</td>
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<tr>
<td>Visibility and traceability</td>
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<tr>
<td>Lean &amp; green energy utilization</td>
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<tr>
<td>Worker/driver quality of life</td>
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<tr>
<td>Packaging materials waste</td>
<td></td>
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<tr>
<td>Traffic &amp; Congestion</td>
<td></td>
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<tr>
<td>Production &amp; storage facilities utilization</td>
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<tr>
<td>Overall inventory</td>
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<tr>
<td>Overproduction waste</td>
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</tbody>
</table>

**Impact Levels:**
- **Strong impact**
- **Significant impact**
- **Low impact**

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## Inefficiency & Unsustainability Symptoms Tackled by Physical Internet

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<th>Supply</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product availability</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
</tr>
<tr>
<td>Delivery speed, precision, cost &amp; lateness</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Significant impact</td>
</tr>
<tr>
<td>Economic lot: truckload&gt;pallet&gt;case&gt;unit</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
</tr>
<tr>
<td>Omnichannel capability</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
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<tr>
<td>Crossborder complexity and delays</td>
<td>Low impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
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<td>Strong impact</td>
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<tr>
<td>International deployment capability</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
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<tr>
<td>City Logistics</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
</tr>
<tr>
<td>Supply chain security</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
</tr>
<tr>
<td>Supply chain robustness and resilience</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
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<tr>
<td>Automation capability</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
</tr>
<tr>
<td>Innovation pace, scope and scale</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
<td>Strong impact</td>
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*Georgia Tech Physical Internet Center*
Better sustainability by encapsulating goods in \( \pi \)-containers: Think of a hybrid between Lego Blocks and Russian Dolls

**Easy to Handle, Store & Transport**
- Robust & reliable
- Snap and interlock
- Load and unload
- Seal and unseal
- Compose & decompose
- Conditioning capable
- Cleanable
- Panel (pub + info)

**Smart & Connected**
- Uniquely identifiable
- Communications capable
- State memory
- *Reasoning capabilities*

**Eco-friendly**
- Light & thin
- Reusable and/or recyclable
- Minimal off-service footprint
- Distinct structural grades

They notably enable
- Better asset utilization through better 3D space usage & avoiding material waste
- Cheap, fast and secure goods flow through multiple hubs, modes & stakeholders
- Ubiquitous supply chain visibility & traceability issues
- Dynamic routing capabilities for better agility and resilience


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Hyperconnected transportation and delivery
Enabling order-of-magnitude efficiency & sustainability improvements

Current
Dedicated assets & flows

Hyperconnected
Relay through openly shared hubs
Flow consolidated through inter-hub transporters

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

Simple case: single-mode, In general: multimodal
Hyperconnected distribution and fulfillment
Enabling order-of-magnitude efficiency & sustainability improvements

Current Distribution
Dedicated assets
Static structure

Hyperconnected Distribution
Deploy stock in openly shared DCs as demand fluctuates

Cloud storage

Manufacturer A
PA1
PA2
DA
D1
S1a
S1e
Retailer 1

Manufacturer B
PB
DB
D2a
D2b
S2a
S2e
S2f
S2j
Retailer 2

Cloud storage

PA1
PB
PA1
O1
O2
O3
O4
O5
O1
S1a
S2a
S2e
S1e
S2f
S2j

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Cloud storage

PA1
PB
PA1

O1
O2
O3
O4
O5
O1

Plant;
Retail Store;
Open hub

Open distribution center

Manufacturer:
Retailer:
Cloud:

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Efficiency & sustainability improvement potential
Assessed through field-based analytics, optimization & simulation studies

Hyperconnected Transportation: Simulation Based Assessment
Carrefour and Casino in France and their 100 top suppliers

Current flows
Hyperconnected flows
Current: Trucks
Hyperconnected: Trucks & Rail

Economical: Up to 32% overall cost saving
Environmental: About 60% reduction of greenhouse gas emissions

2014 PREDIT Best International Collaboration Award
Ballot É., B. Montreuil, R. Meller (2015),
The Physical Internet: The Network of Logistics Networks, Documentation Française.
Hyperconnected Distribution: Optimization Based Assessment

Hyperconnected distribution is by far the best alternative, even better as consumer delivery has to be faster.

Source: H. Sohrabi, B. Montreuil, W. Klibi: Collaborative and Hyperconnected Distribution Systems: A Comparative Optimization-Based Assessment, ISERC 2016, USA
Business taking charge
Validating feasibility & creating stimulating successes and role models

- Pay per use BM (price ½ supplier – ½ retailer)
- CO2 emission reduction: -25%
- From -5% to -15% of direct cost saving
- Delivery frequency improvement
- King of the Supply Chain Award 2016 in France

Adapted from a slide assembled by Prof. Eric Ballot, January 2016
Enables efficient & sustainable order-of-magnitude capability improvement of businesses, industries and territories

Ex: Omnichannel, Responsiveness, Synchromodality, Agility, Scalability, Resilience

Enables across-the-board order-of-magnitude Improvement of economic, environmental & societal efficiency & sustainability

Improving the playing field across territories, industries and businesses worldwide
Physical Internet enabled capability improvement
Results from a real case inspired simulation study of hyperconnected mixing center

Hyperconnected mixing center enables manufacturers serving retailers in a region to increase delivery frequency clients while reducing total travel

<table>
<thead>
<tr>
<th>Scenario ID</th>
<th>Average Inter-Delivery Time in Days and Marginal Reduction</th>
<th>Average Marginal Reduction in Outbound Travel Distances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No MC</td>
<td>Dedicated MC</td>
</tr>
<tr>
<td>1</td>
<td>8.8</td>
<td>2.6</td>
</tr>
<tr>
<td>2</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>3</td>
<td>13.7</td>
<td>11.4</td>
</tr>
<tr>
<td>4</td>
<td>11.1</td>
<td>9.1</td>
</tr>
<tr>
<td>5</td>
<td>12.6</td>
<td>11.4</td>
</tr>
<tr>
<td>6</td>
<td>16.1</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Kim N. & B. Montreuil, Simulation-based Assessment of Hyperconnected Mixing Center Capacity Requirements and Service Capabilities, IPIC 2017, Graz, Austria.
Businesses Develop Business Models
Enabling Hyperconnected Distribution & Fulfillment

Dynamically deploying products for rapid on-demand fulfillment
Exploiting Physical Internet principles, Beyond client dedicated facilities and services

Business taking charge
Validating feasibility & creating stimulating successes and role models

ES3
Openly shared automated DC
Multi-manufacturer: full load inbound
Multi-retailer full load outbound
Enables Direct-to-store
Medium-to-Long-Term Commitment

Flexe.com
On-Demand Warehousing
Asset-free platform
Multi-warehouse, Multi-User
AirBnB-like shared economy model
Pay-per-Use

Fulfillment-By-Amazon
First Open Large-Scale Asset-Based Storage and Fulfillment Service Provider
Asset-Intensive: US fulfillment center network
Open to any vendor, selling or not on Amazon
Inspired by Amazon’s huge success in cloud storage

適宜共享自動化的DC
多廠家: 整體載入
多零售商: 整體載出
直接到儲
中到長期承諾

Flexe.com
按需存儲
無資產平台
多倉庫, 多用戶
AirBnB式的共享經濟模式
按次使用

Fulfillment-By-Amazon
首個開放大規模資產存儲和履行服務供應商
資產密集型: 美國履進中心網絡
對任何供應商開放, 售或其他
受Amazon的雲存儲巨大成功啟發
Even though a single instance of each type of facility/entity is drawn, a networked combination of them may be engaged in producing and flowing an order.
All lines are bilateral to emphasize the flow of purchased and returned goods.
All lines indicate a flow that may be instantiated using multiple modes and being crossdocked/ transshipped through multiple hubs.

Exploiting hyperconnected transportation & delivery

Deliveries performed through Physical Internet enabled hyperconnected freight transportation, orchestrated by contracted third-party delivery orchestrators.

Exploiting hyperconnected fulfillment


Physical Internet enabled capability Improvement
Enabling efficient & responsive hyperconnected omnichannel logistics & supply chains


Physical Internet: Impact synopsis
Efficiency, sustainability, capabilities and competitiveness

Enables **competitiveness** improvement of smart hyperconnected businesses, industries and territories

Exploiting/Enabling PI

Reduces **competitiveness** of businesses, industries and territories thriving from system inefficiencies

Incapable or unwilling to adapt to PI

Enables efficient & sustainable order-of-magnitude **capability** Improvement of businesses, industries and territories

Ex: Omnichannel, Responsiveness, Synchronomodality, Agility, Scalability, Resilience

Enables across-the-board order-of-magnitude Improvement of economic, environmental & societal **efficiency & sustainability**

Improving the playing field across territories, industries and businesses worldwide
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Focus on the MOVE business
Covering freight/parcel transportation/shipping/delivery

Worldwide total revenues from transportation/delivery services
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Big, bad & ugly fear of services providers

Current Business

Perceived Future MOVE Business
As Physical Internet Improves Efficiency

Externalized

Externalized

Less Miles & Shipments
Less Drivers/Vehicles
Less Business
More Cutthroat Competition

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
Broader Picture of PI Induced MOVE Business Evolution

Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Declining MOVE Demand
Growing Share for Third-Party Carrier & Logistics Service Provider Community

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Extended focus on the MOVE+DEPLOY business
Covering freight/parcel transportation/shipping/delivery
Storage/Warehousing/Distribution/Fulfillment

Externalized MOVE & DEPLOY Business

MOVE

DEPLOY
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Big, bad & ugly fear of services providers

**MOVE**

**DEPLOY**

**Current Business**

**Perceived Future**

**MOVE + DEPLOY Business**

As Physical Internet Improves Efficiency

Less Miles & Shipments / Less Stock
Less Drivers/Vehicles/Facilities
Less Business
More Cutthroat Competition

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
DEPLOY here covers Storage/Warehousing/Distribution/Fulfillment
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

**Broader Picture of PI Induced MOVE+DEPLOY Business Evolution**

- **Internalized**
- **Externalized**

**Declining Overall MOVE & DEPLOY Demand**

Growing Share for Third-Party Carrier & Logistics Service Provider Community

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
DEPLOY here covers Storage/Warehousing/Distribution/Fulfillment
Physical Internet enabled competitiveness
The case of transportation/logistics service providers

Broad Picture of PI Induced MOVE+DEPLOY+REALIZE Business Evolution

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
DEPLOY here covers Storage/Warehousing/Distribution/Fulfillment
REALIZE here covers Manufacturing/3D Printing/Recycling/Personalizing

Declining Overall Demand
Growing Share for Service Providers

MOVE
DEPLOY
REALIZE

Internalized
Externalized
Internalized

Moving here covers Freight/Parcel Transportation/Shipping/Delivery
Deploying here covers Storage/Warehousing/Distribution/Fulfillment
Realizing here covers Manufacturing/3D Printing/Recycling/Personalizing

Declining Overall Demand
Growing Share for Service Providers

Externalized
Internalized
Internalized

Internalized

Externalized

Declining Overall Demand
Growing Share for Service Providers
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Questions, comments and ideas are most welcome

Georgia Tech’s Physical Internet Lab