Georgia Tech Physical Internet Center
Supply Chain & Logistics Institute

Sustainability and Competitiveness
Is the Physical Internet a Solution?

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International Physical Internet Conference

Graz, Austria
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Georgia Tech Physical Internet Center
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Defining the Physical Internet

Hyperconnected global logistics system

enabling seamless open asset sharing and flow consolidation

through standardized

encapsulation, modularization, protocols and interfaces

Image source: clyderathbone.com

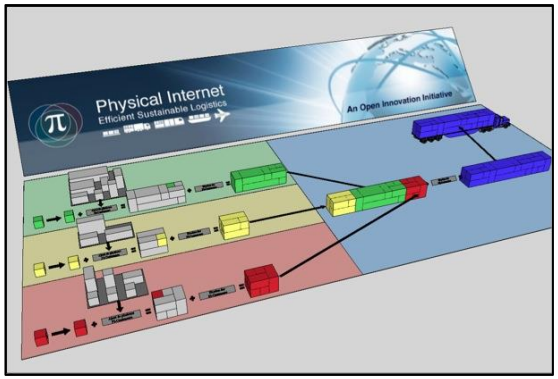
A system is said to be hyperconnected when its components (agents, things, etc.) are intensely interconnected on multiple layers, ultimately anytime, anywhere

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

Hyperconnected system definition by B. Montreuil, July 2015
PI definition adapted by Montreuil B, R.D. Meller & E. Ballot, June 2015
from Montreuil B., R.D. Meller & E. Ballot (2012). Physical Internet Foundations, In: Service Orientation in Holonic and Multi Agent Manufacturing and Robotics, edited by T. Borangiu et al., Springer.

Physical Internet building blocks

Toward an Hyperconnected Logistics Infrastructure



B. Montreuil & C. Thivierge, 2011

Certified Open Logistics Service Providers

Open Logistics Decisional & Transactional Platforms

Global Logistics Monitoring System

Certified Open Logistics Facilities and Ways

Standard Logistics Protocols

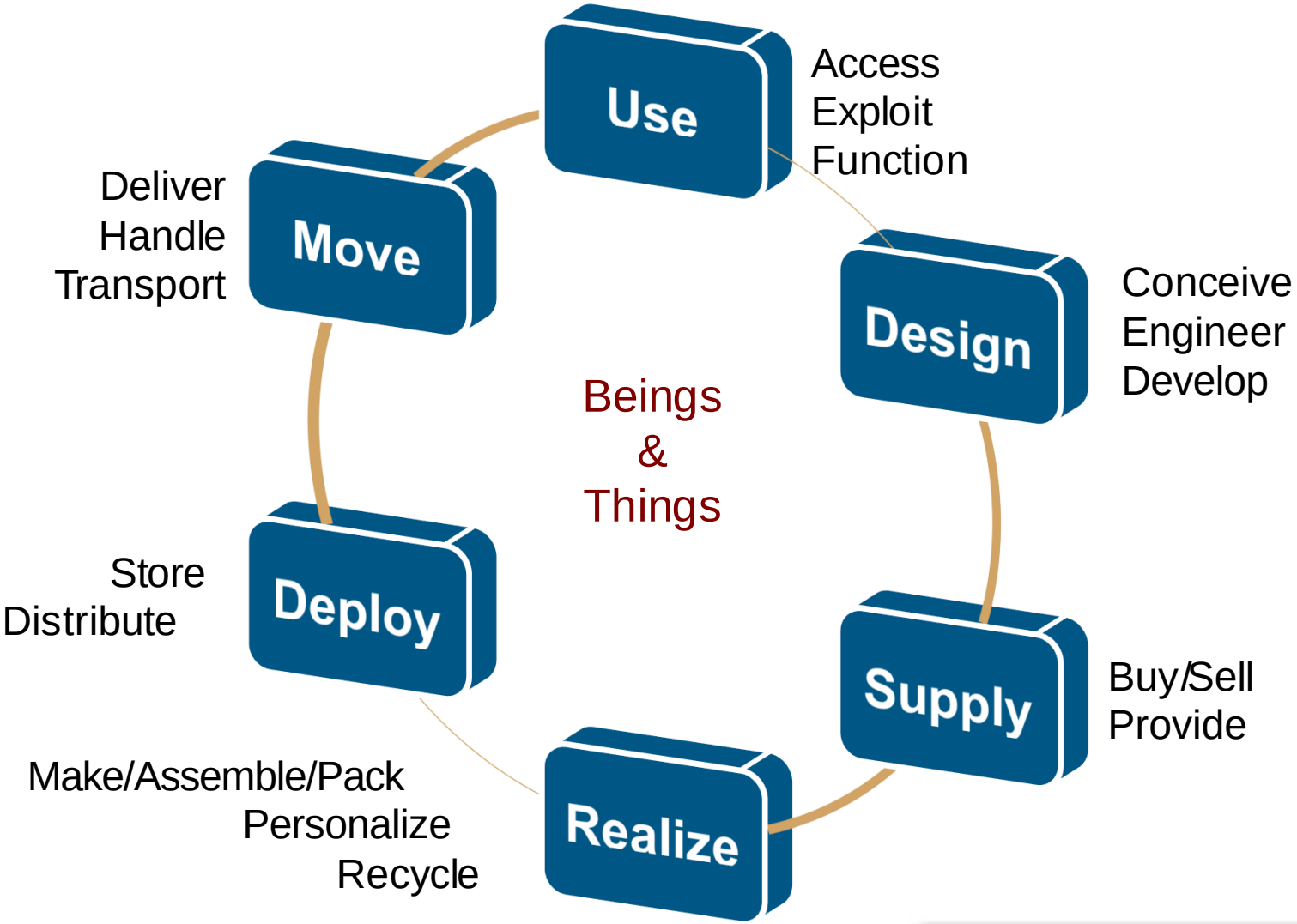
Containerized Logistics Equipment and Technology

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



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

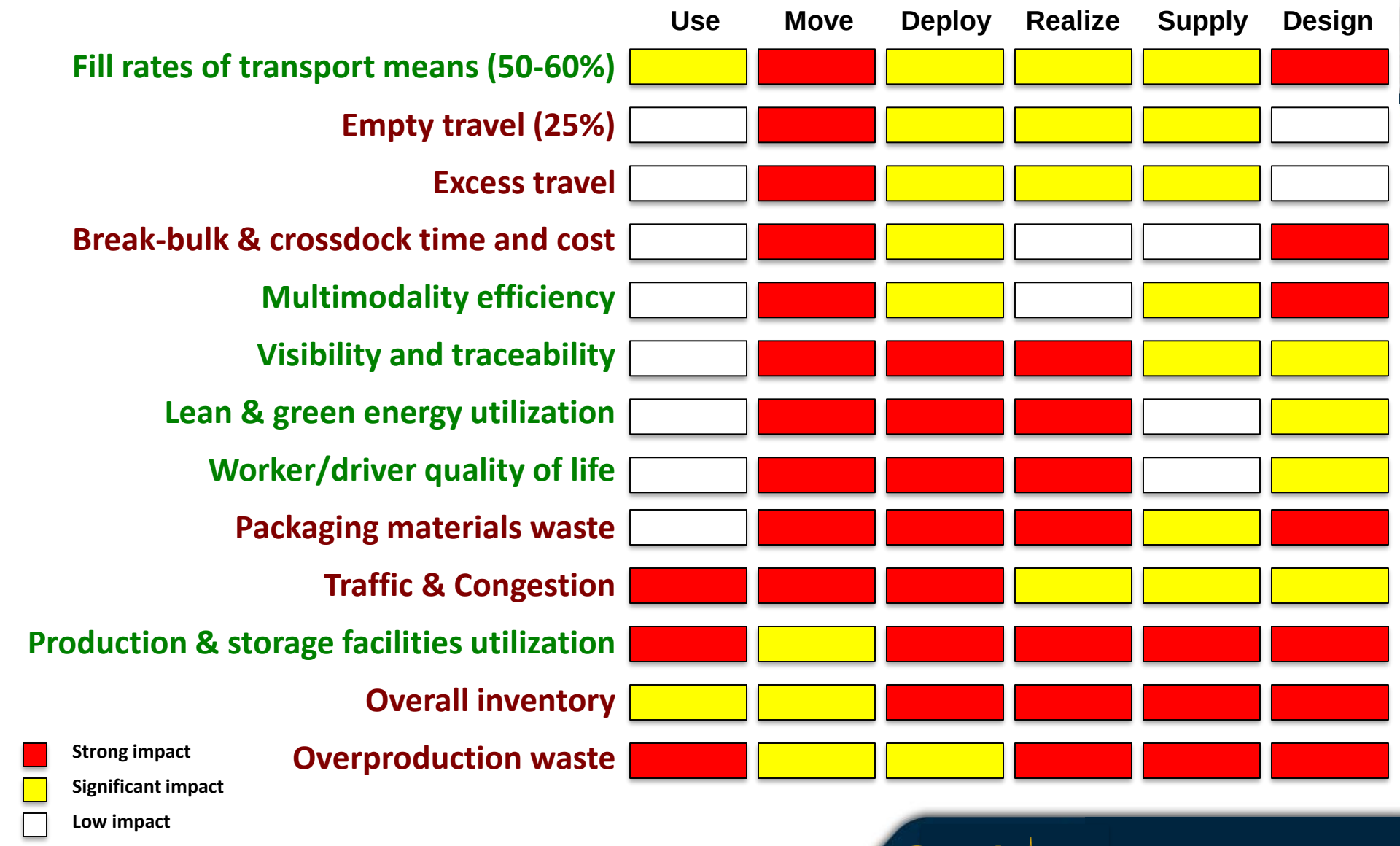
Induced cost reduction
Price reduction
Business opportunity
Economic development opportunity

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

Improved
Quality of life
Goods accessibility
Faster more precise delivery
Novel service capabilities

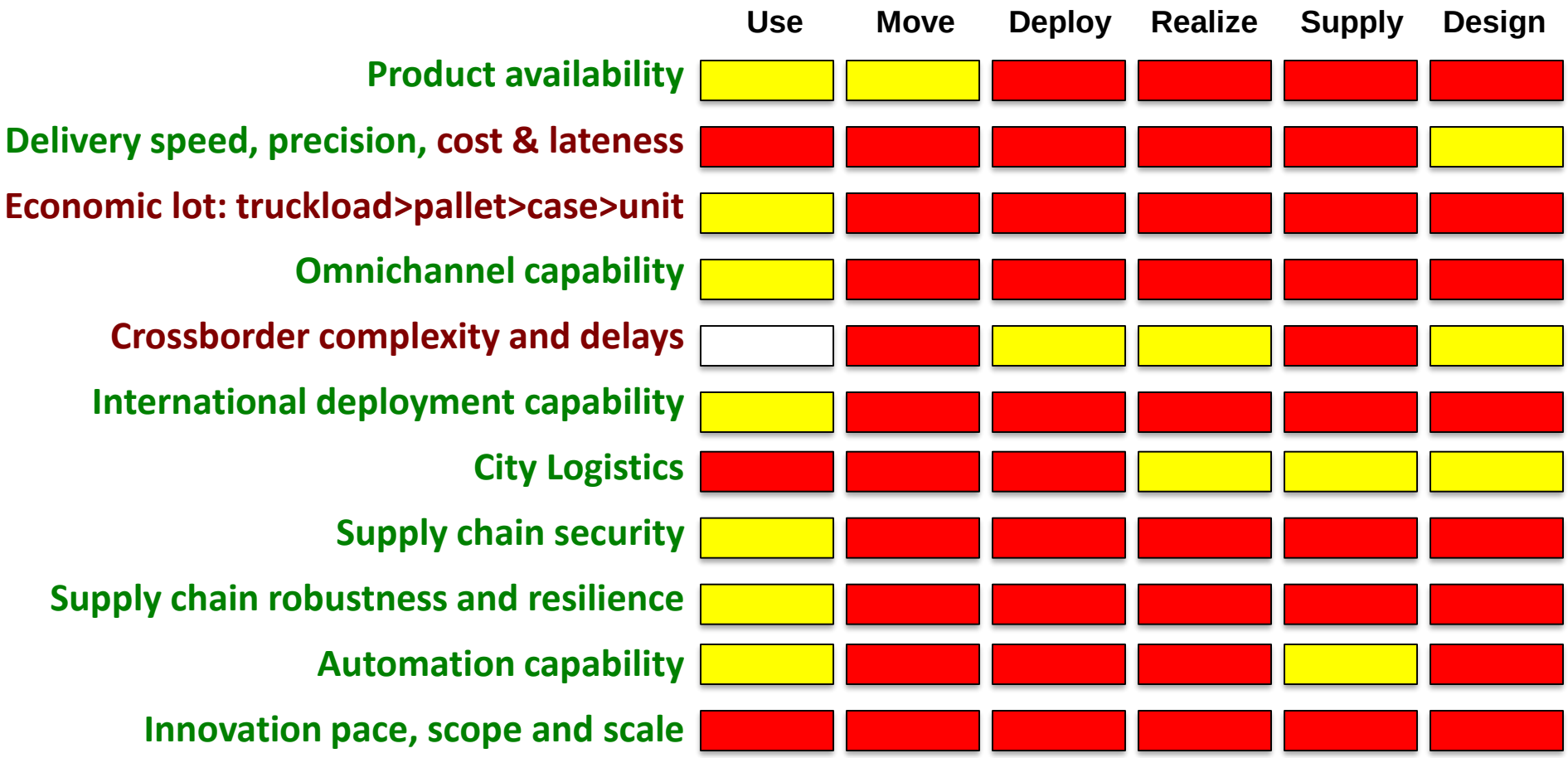
inefficiency & unsustainability symptoms tackled by Physical Internet

Highlighting Impact of Activity Types



inefficiency & unsustainability symptoms tackled by Physical Internet

Highlighting Impact of Activity Types



Better sustainability by encapsulating goods in π-containers:
Think of a hybrid between Lego Blocks and Russian Dolls

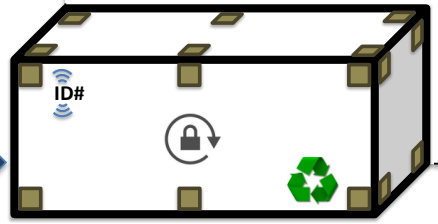
Easy to Handle, Store & Transport
- Robust & reliable
- Snap and interlock
- Load and unload
- Seal and unseal
- Compose & decompose
- Conditioning capable
- Cleanable
- *Panel (pub + info)*

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

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

Protect the encapsulated objects

Standard Modular



Factories

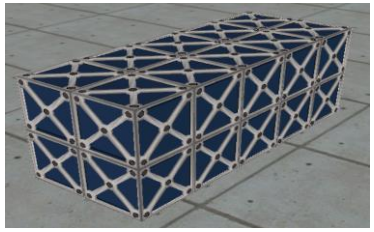
Clients (Retail shelves, Homes)

Products ever better designed for encapsulation

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

Transport Containers
Modular fit in π-certified vehicles

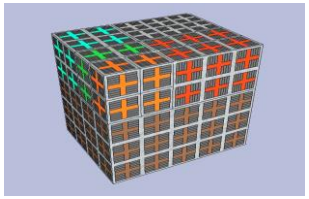
π-Pod



12; 6; 4,8; 3,6; 2,4; 1,2m

Handling Containers
Modular fit in transport containers

π-Box



Packaging Containers
Modular fit in handling containers

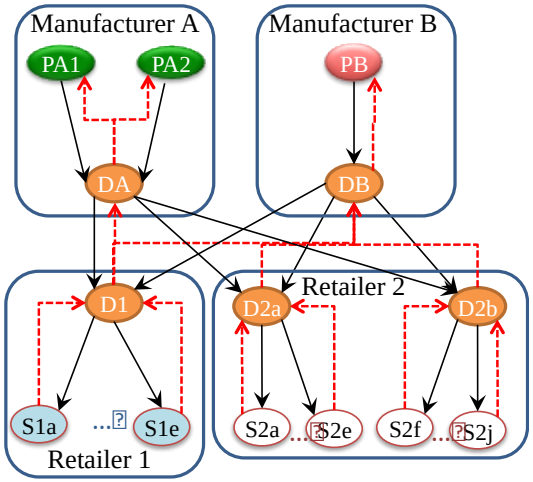
π-Pack

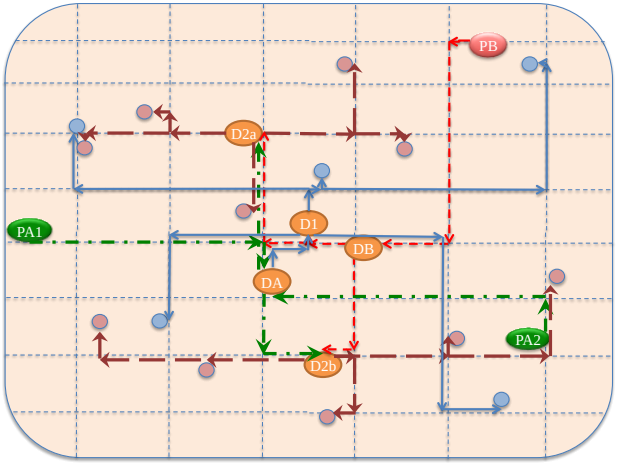
1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1m -ε

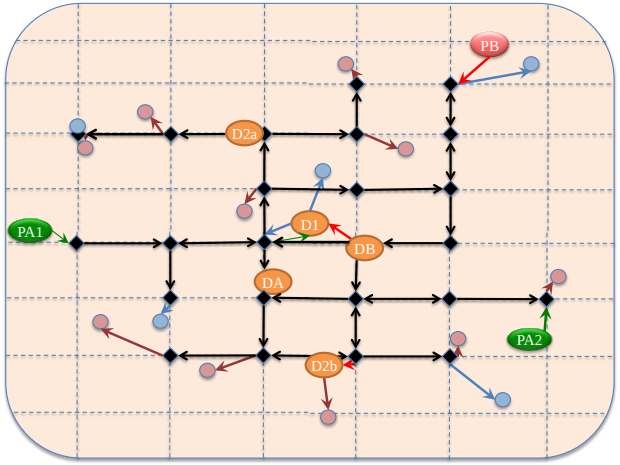
Montreuil B., E. Ballot, W. Tremblay (2016).
Modular Design of Physical Internet Transport, Handling and Packaging Containers,
Progress in Material Handling Research Vol. 13, Ed. J. Smith et al., MHI, Charlotte, NC, USA.

Hyperconnected transportation and delivery

Enabling order-of-magnitude efficiency & sustainability improvements







Client order

Physical flow

P# : Plant

: Retail store

S# Private distribution center

Current

Dedicated assets & flows

Hyperconnected

Relay through openly shared hubs

Flow consolidated through inter-hub transporters

Simple case: single-mode, In general: multimodal

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

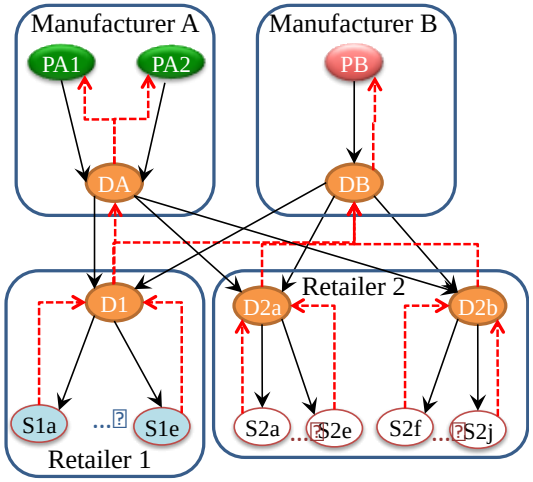
Hyperconnected distribution and fulfillment

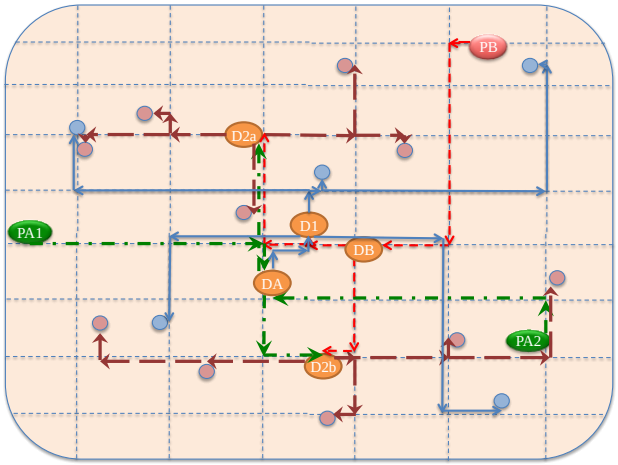
Enabling order-of-magnitude efficiency & sustainability improvements

Current Distribution

Dedicated assets

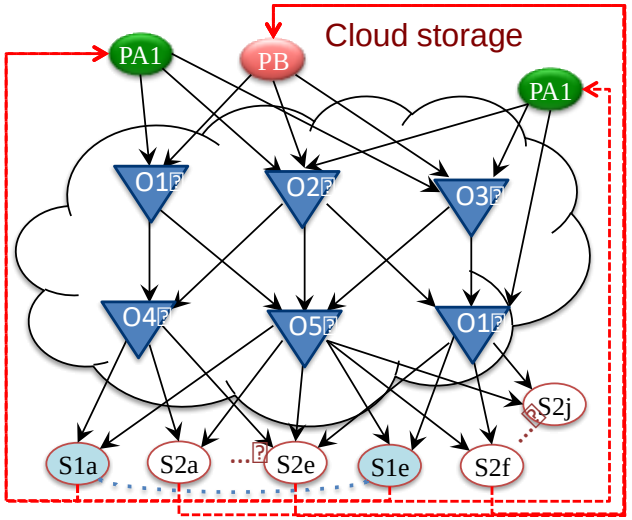
Static structure

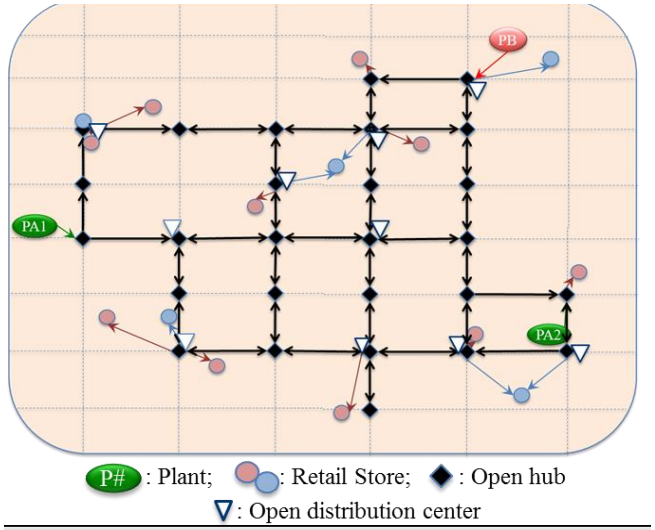




Hyperconnected Distribution

Deploy stock in openly shared DCs as demand fluctuates





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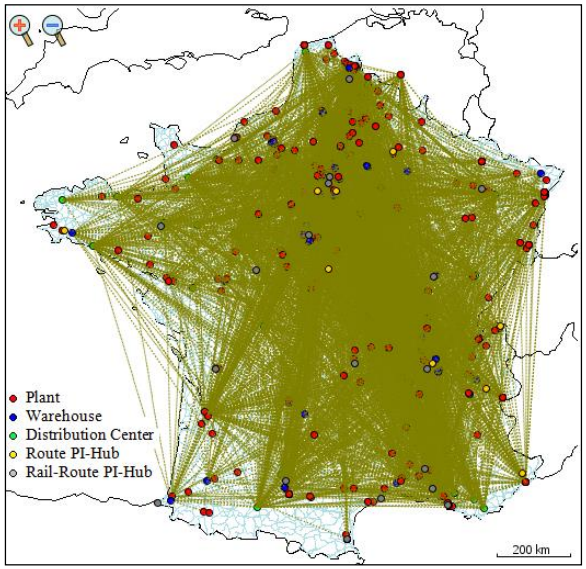
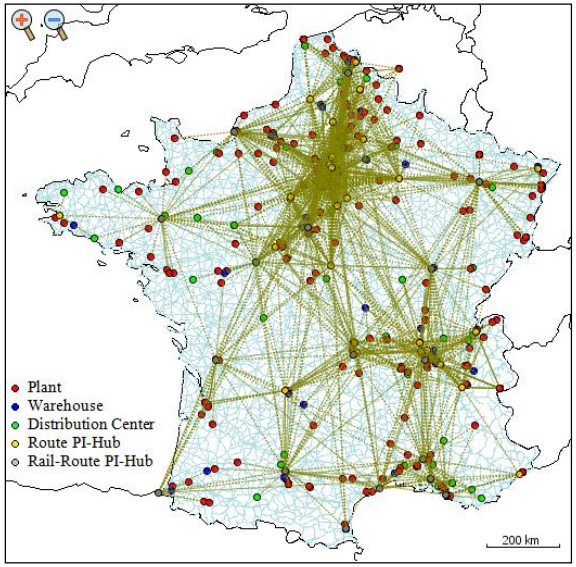
Hyperconnected Transportation: Simulation Based Assessment

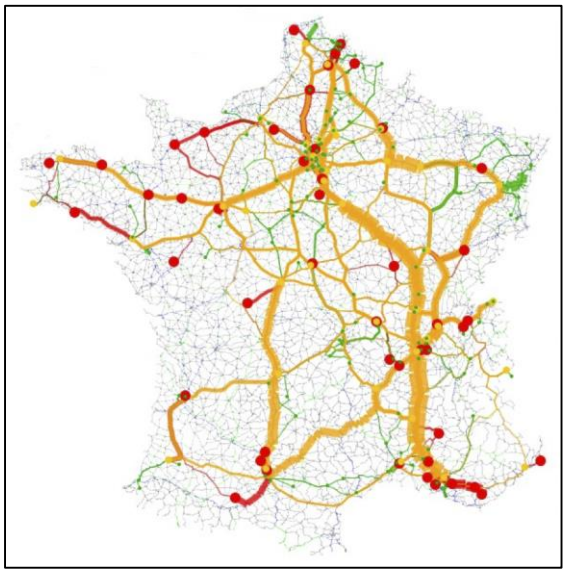
Carrefour and Casino in France and their 100 top suppliers



Current flows



Hyperconnected flows



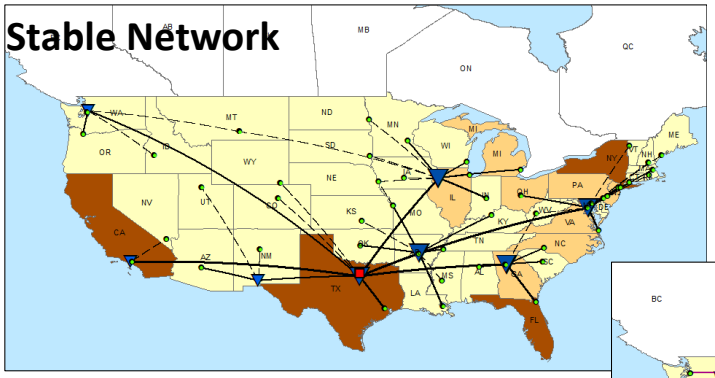
Current: Trucks
Hyperconnected: Trucks & Rail

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

2014 PREDIT Best International Collaboration Award

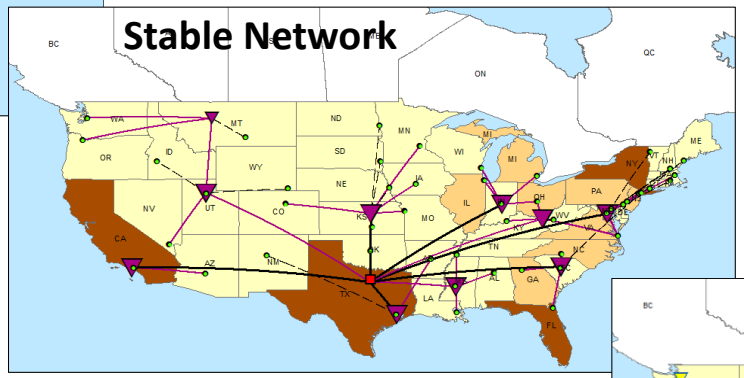
Ballot É., B. Montreuil, R. Meller (2015),
The Physical Internet: The Network of Logistics Networks, Documentation Française.

Hyperconnected Distribution: Optimization Based Assessment



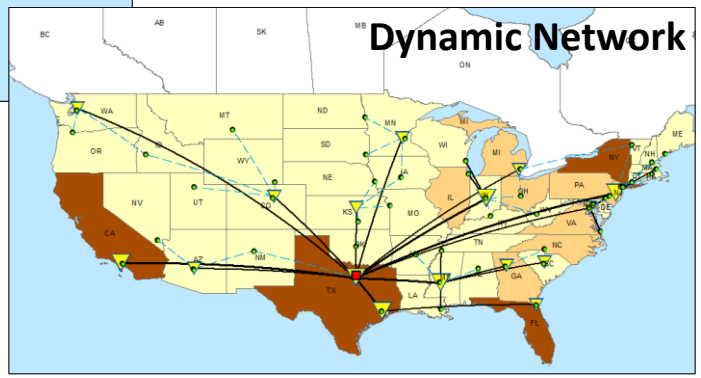
Dedicated Distribution

Cost: -11%



Collaborative Distribution
2 partners

Cost: -25%



Hyperconnected Distribution

Cost: -33%

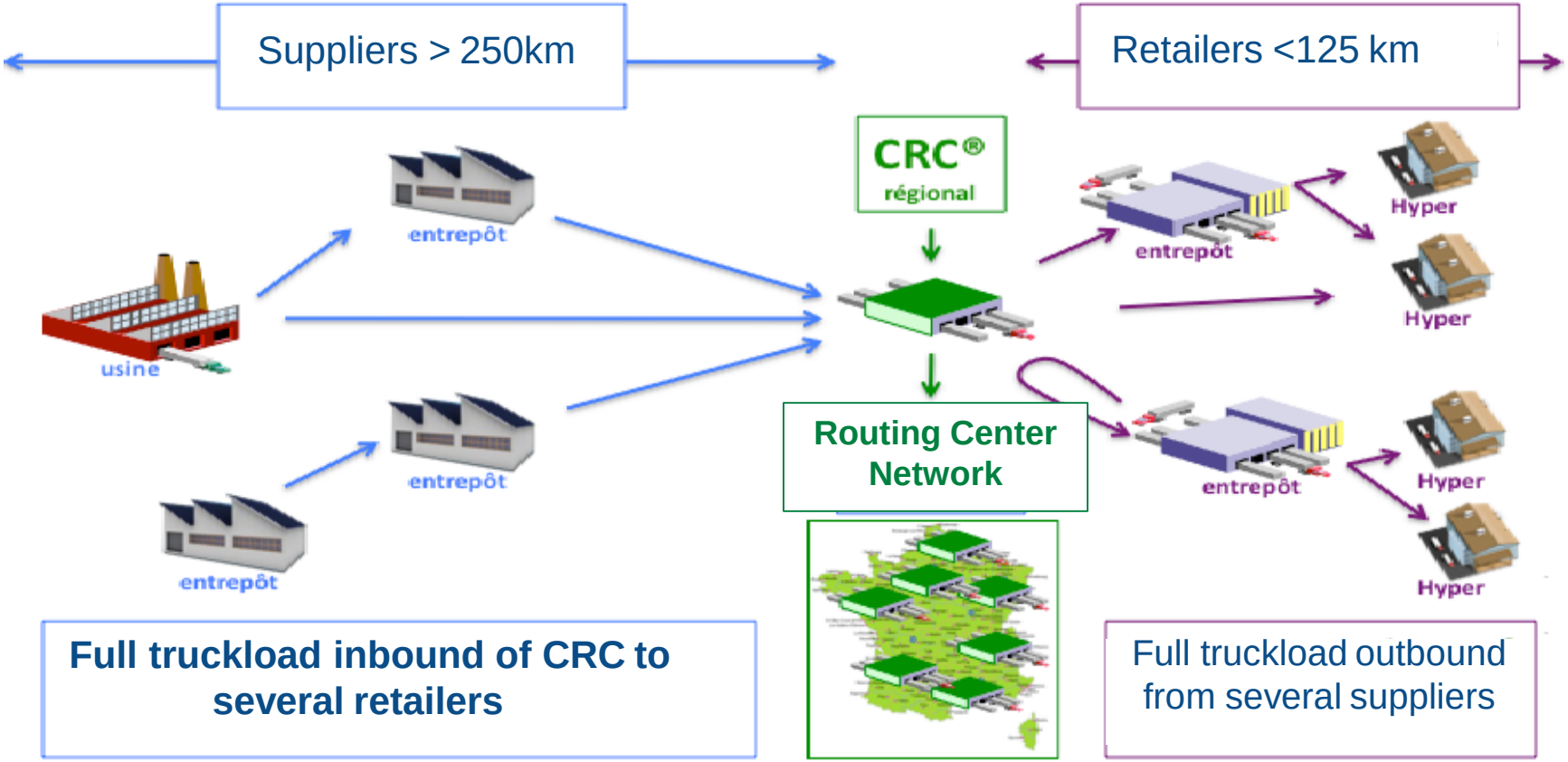
Hyperconnected distribution is by far the best alternative, even better as consumer delivery has to be faster

1-2-3-Day Service Level

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**

CRC® Services

Adapted from a slide assembled by Prof. Eric Ballot, January 2016

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

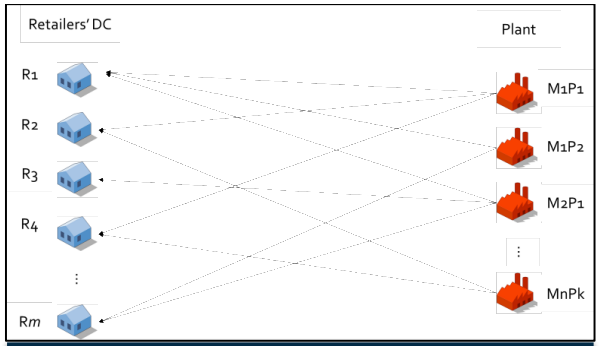
Ex: Omnichannel, Responsiveness, Synchromodality, Agility, Scalability, Resilience

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

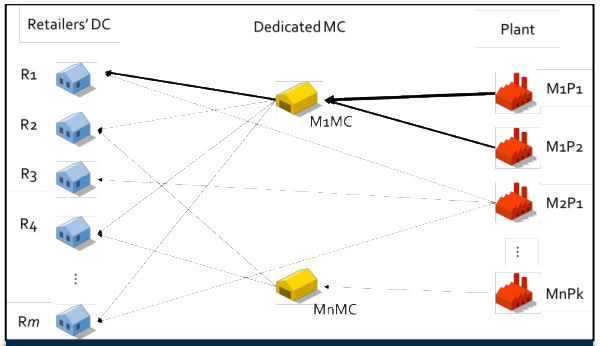
Improving the playing field across territories, industries and businesses worldwide

Physical Internet enabled capability improvement

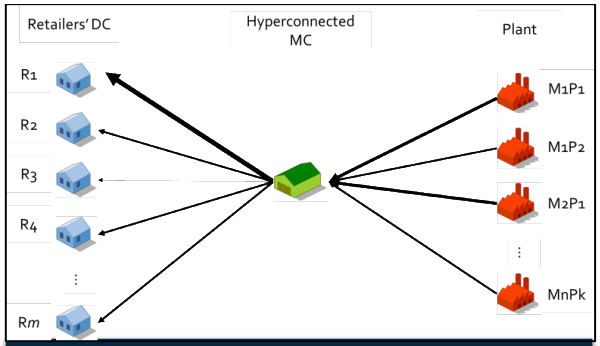
Results from a real case inspired simulation study of hyperconnected mixing center



No MC (Plant Warehouses)

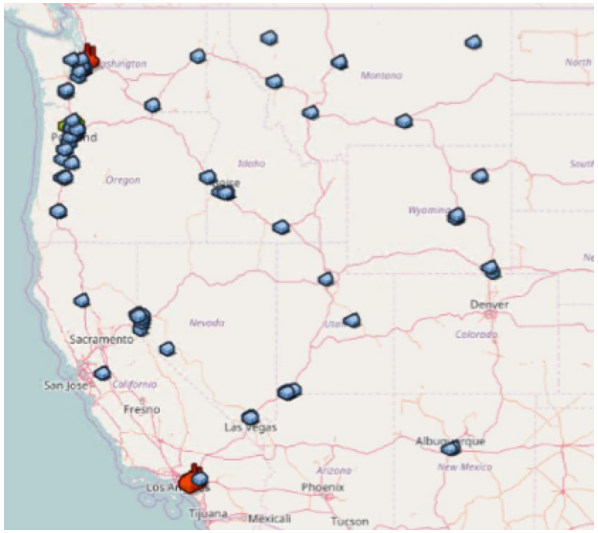


Dedicated MC



Hyperconnected MC

150 manufacturers & 200 retailer DCs



Blue: Retailer DC
Red: Factory, most not shown as outside this territory

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

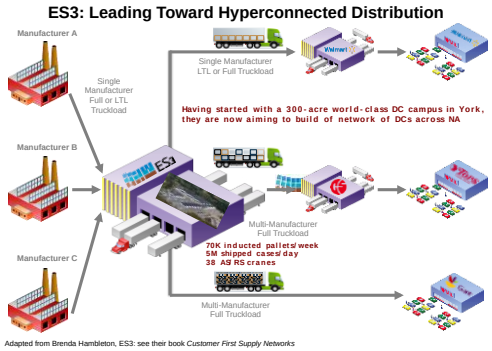
Scenario ID	Average Inter-Delivery Time in Days and Marginal Reduction					Average Marginal Reduction in Outbound Travel Distances	
	No MC	Dedicated MC		Hyper MC		From No MC to Dedicated MC	From Dedicated MC to Hyper MC
1	8.8	2.6	71%	2.1	18%	67%	1%
2	6.4	6.4	0%	3.4	46%	0%	59%
3	13.7	11.4	17%	4.7	59%	27%	40%
4	11.1	9.1	18%	2.3	75%	24%	39%
5	12.6	11.4	9%	4.3	62%	18%	51%
6	16.1	14.9	7%	9.7	35%	19%	55%

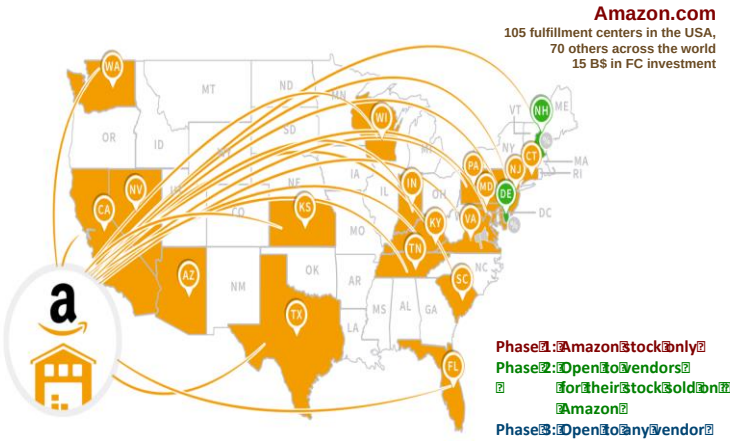
Kim N. & B. Montreuil, Simulation-based Assessment of Hyperconnected Mixing Center Capacity Requirements and Service Capabilities, IPIC 2017, Graz, Austria.

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





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

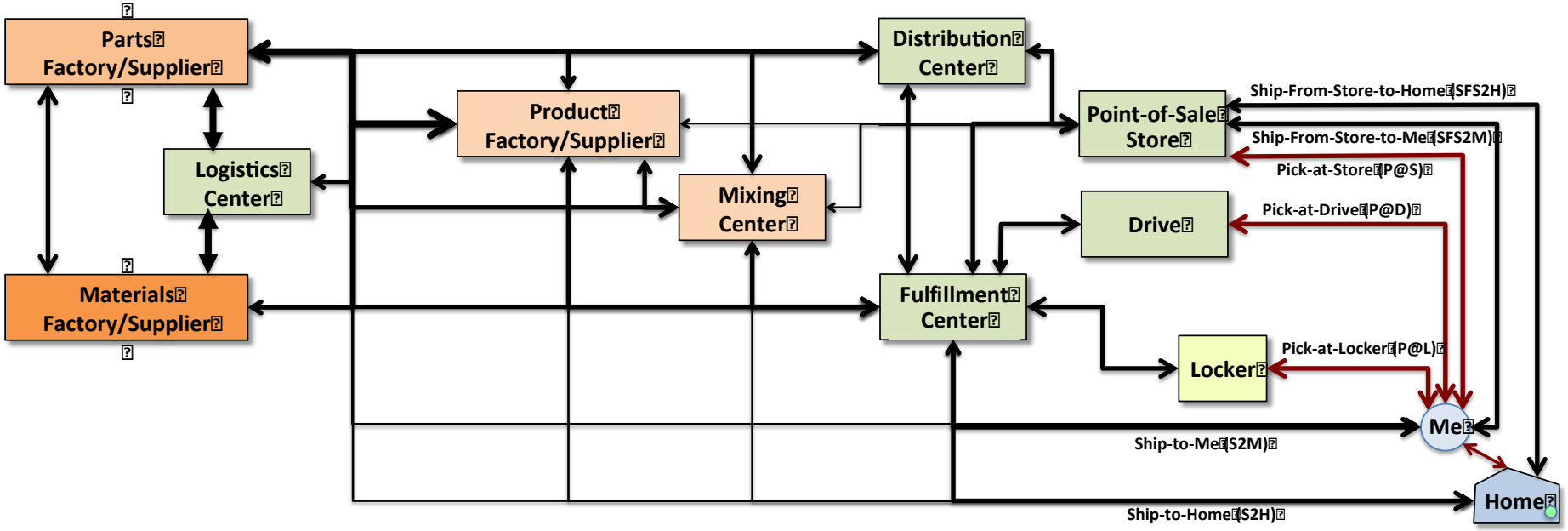
On-Demand Warehousing
Asset-free platform
Multi-warehouse, Multi-User
AirBnB-like shared economy model
Pay-per-Use

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

Physical Internet enabled capability Improvement

Enabling efficient & responsive hyperconnected omnichannel logistics & supply chains



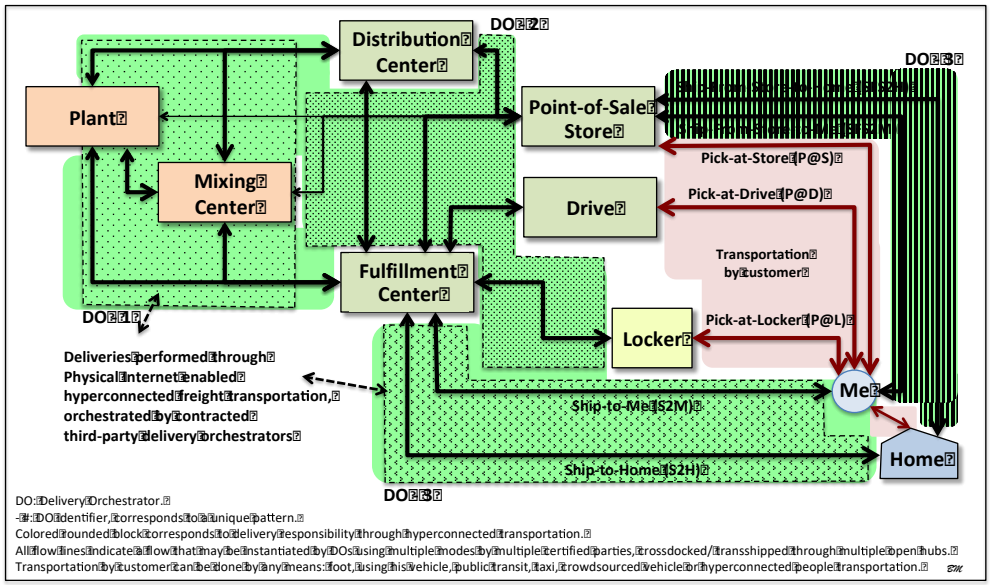
Even though a single instance of each type of facility/entity is drawn, a networked combination of them may engaged in producing and flowing an order
All lines are bilateral to emphasize the flow of purchased and returned goods
All lines indicate a flow that may be instantiated using multiple modes and being crossdocked/transshipped through multiple hubs

Adapted from Montreuil B. (2017). *Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities*,
Progress in Material Handling Research Vol. 14, Ed. K. Ellis et al., MHI, Charlotte, NC, USA

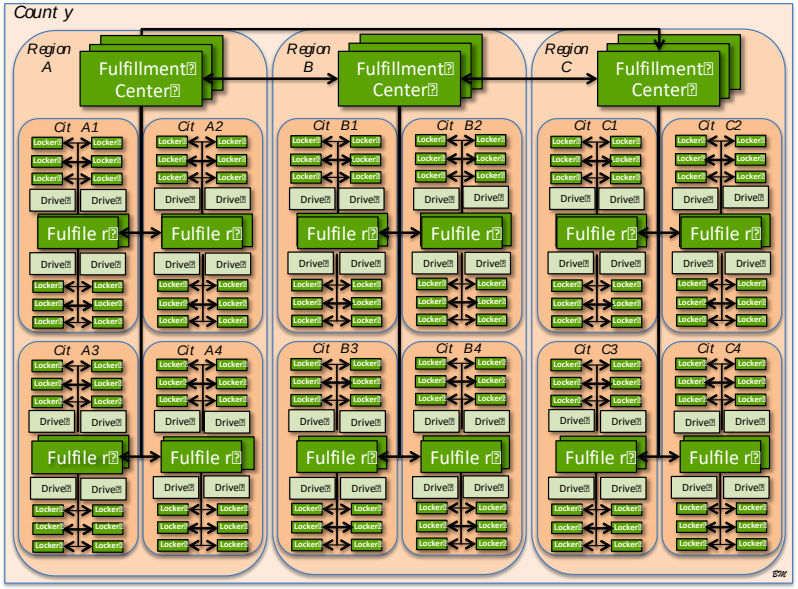
Physical Internet enabled capability Improvement

Enabling efficient & responsive hyperconnected omnichannel logistics & supply chains

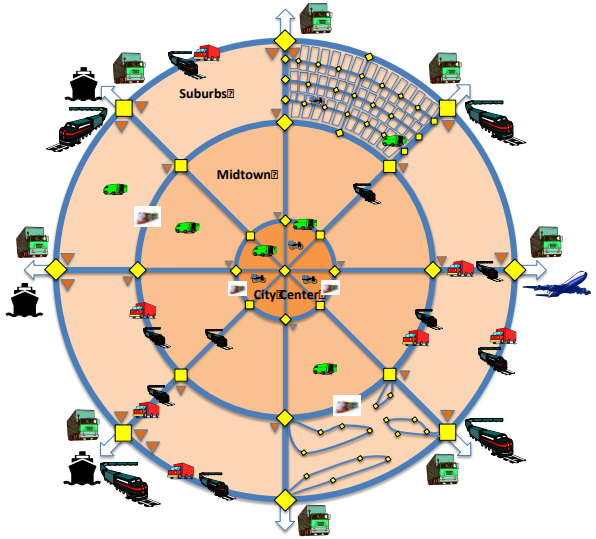
Exploiting hyperconnected transportation & delivery



Exploiting hyperconnected fulfillment



Exploiting hyperconnected city logistics

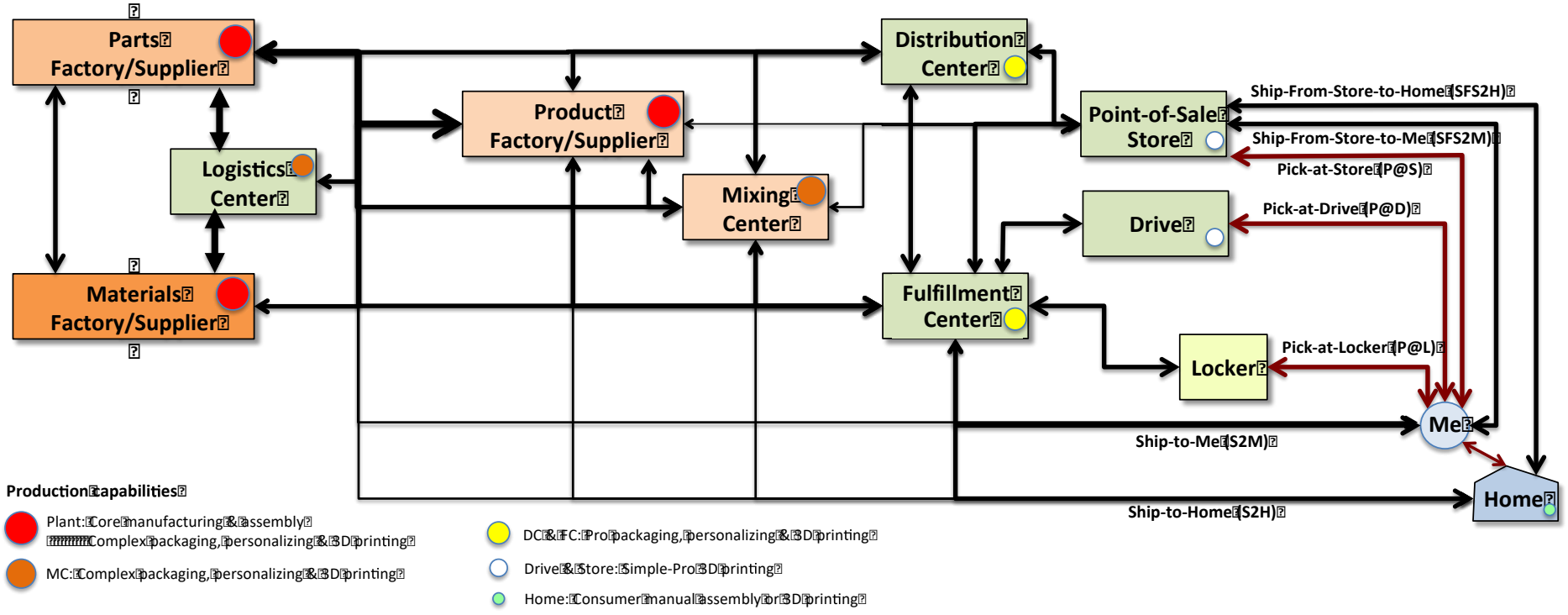


Crainic T. G. & B. Montreuil (2016). *Physical Internet Enabled Hyperconnected City Logistics*, **Transportation Research Procedia – 10th International Conference on City Logistics, v12**, 383-398.

Montreuil B. (2017). *Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities*, **Progress in Material Handling Research Vol. 14**, Ed. K. Ellis et al., MHI, Charlotte, NC, USA

Physical Internet enabled capability Improvement

Enabling efficient & responsive hyperconnected omnichannel logistics & supply chains



Adapted from Montreuil B. (2017). *Omnichannel Business-to-Consumer Logistics and Supply Chains: Towards Hyperconnected Networks and Facilities*,
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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, 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

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

Worldwide total revenues from transportation/delivery services

Big, bad & ugly fear of services providers

Current Business

Externalized

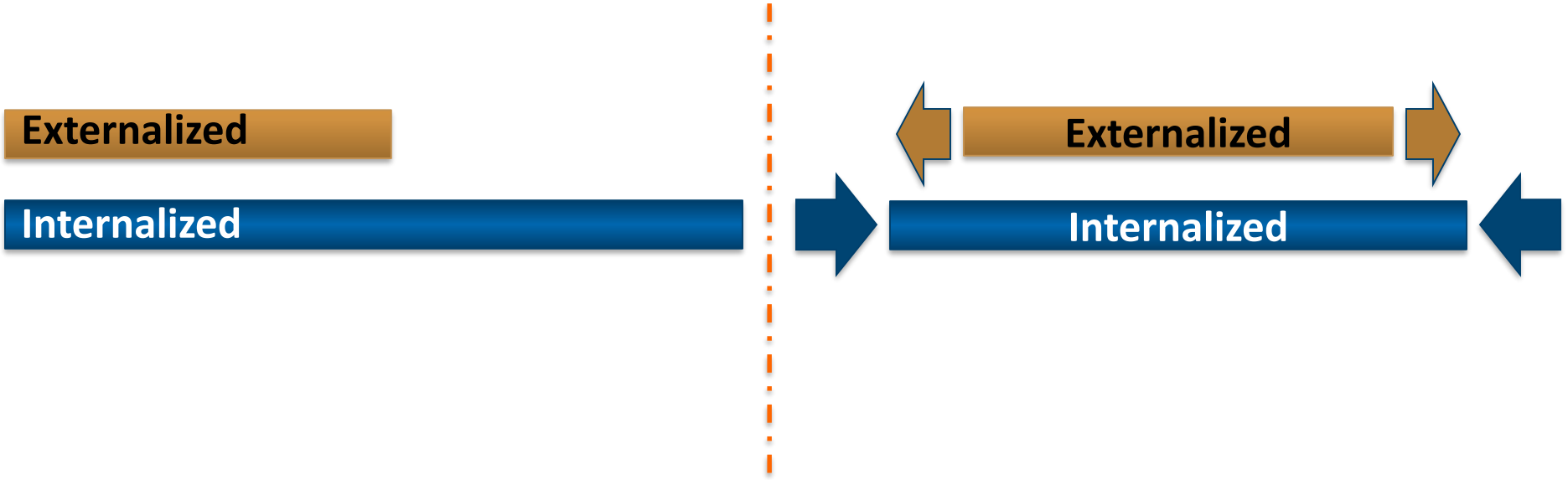
Perceived Future MOVE Business
As Physical Internet Improves Efficiency

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



Declining MOVE Demand

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

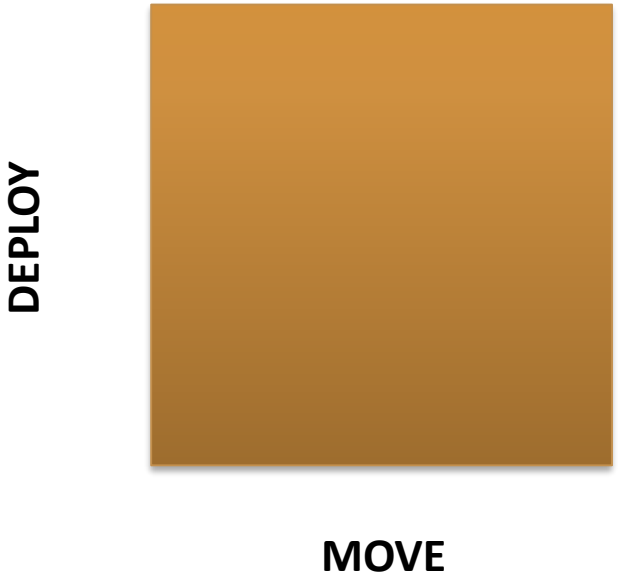
MOVE here covers Freight/Parcel Transportation/Shipping/Delivery

Extended focus on the MOVE+DEPLOY business

Covering freight/parcel transportation/shipping/delivery

Storage/Warehousing/Distribution/Fulfillment

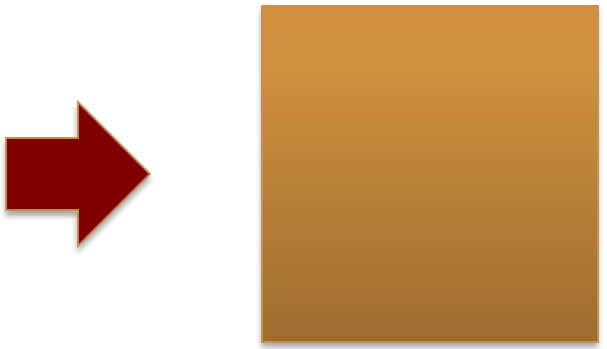
Externalized MOVE & DEPLOY Business



Big, bad & ugly fear of services providers

Current Business

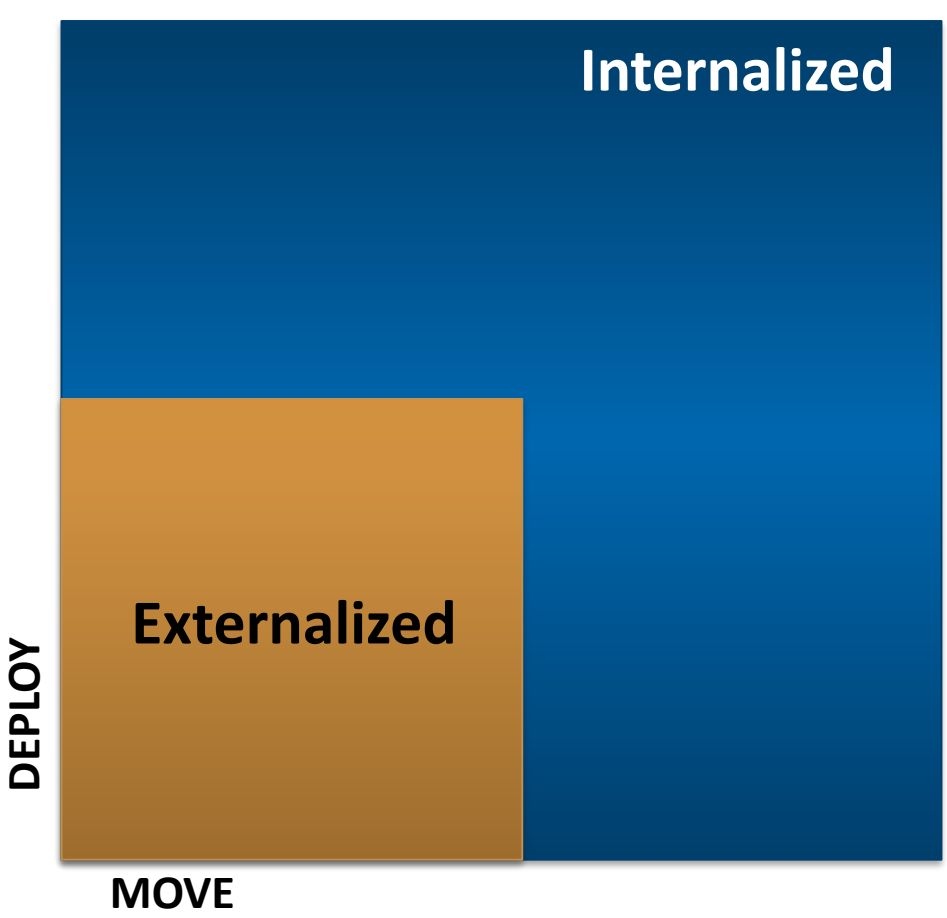
Perceived Future
MOVE+DEPLOY Business
As Physical Internet Improves Efficiency

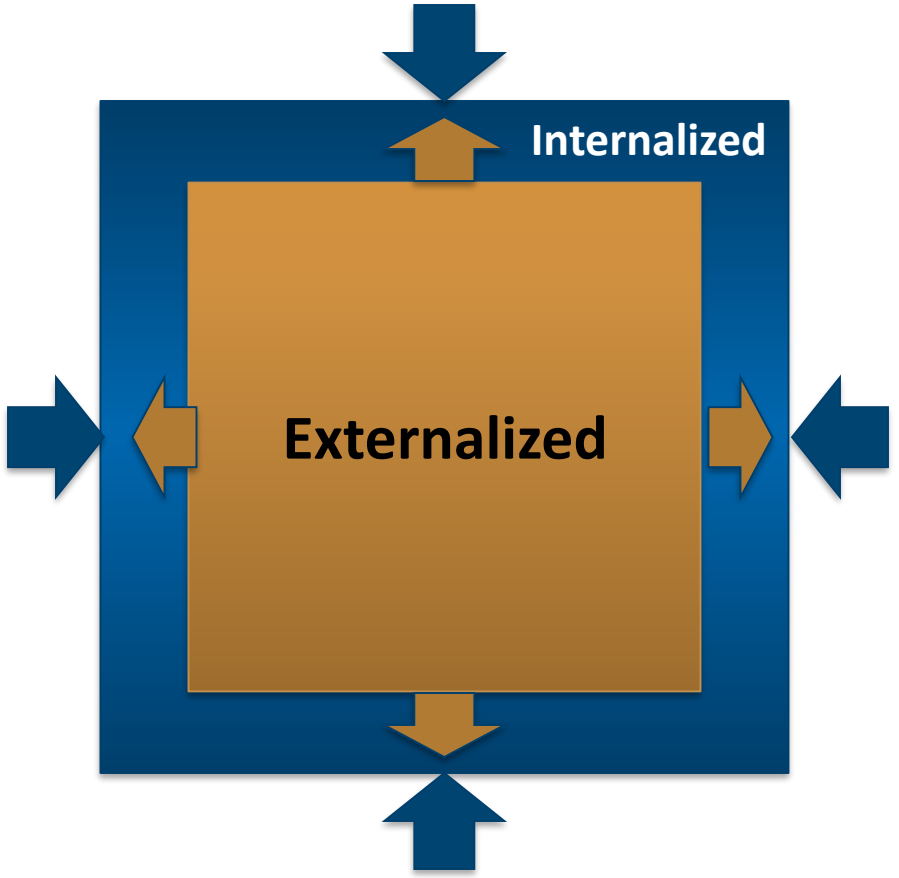


Less Miles & Shipments / Less Stock
Less Drivers/Vehicles/Facilities
Less Business
More Cutthroat Competition

MOVE here covers Freight/Parcel Transportation/Shipping/Delivery
DEPLOY here covers Storage/Warehousing/Distribution/Fulfillment

Broader Picture of PI Induced MOVE+DEPLOY Business Evolution



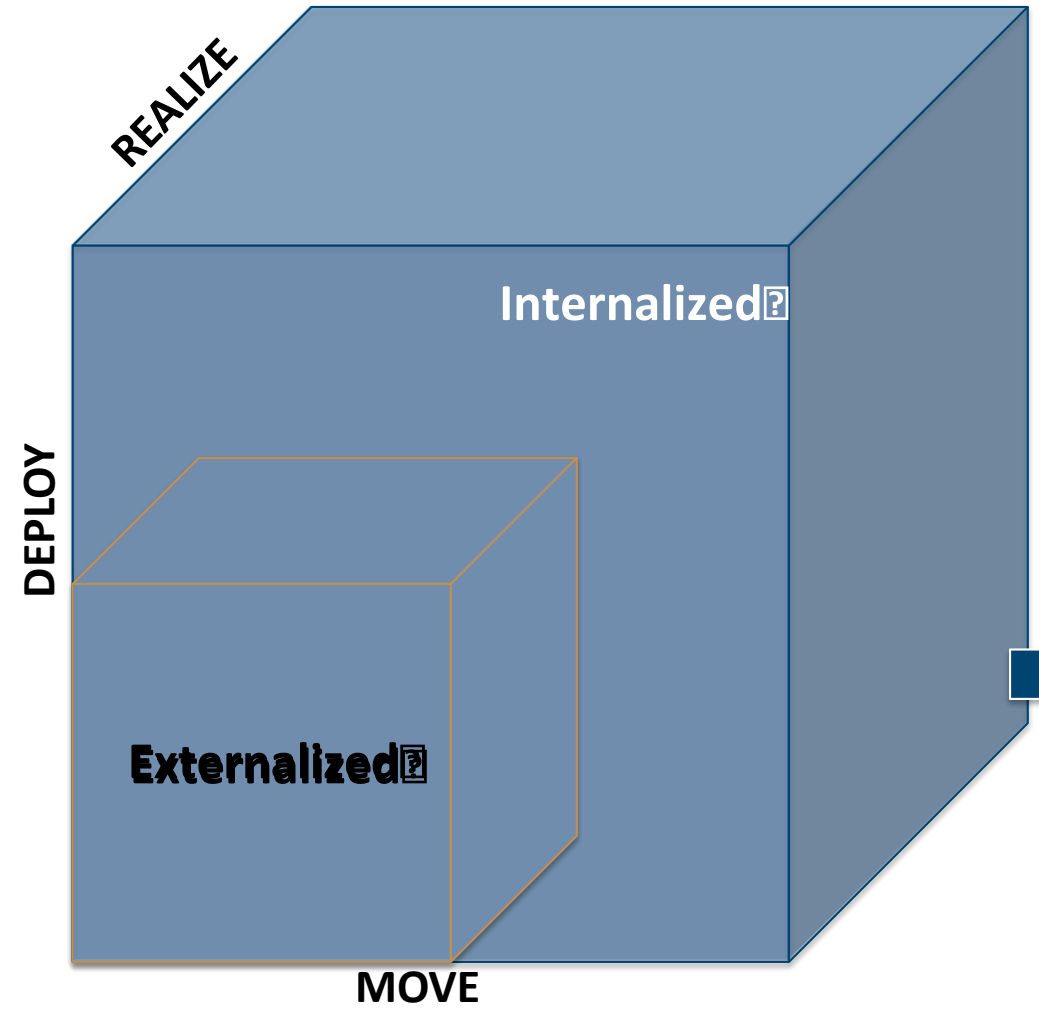


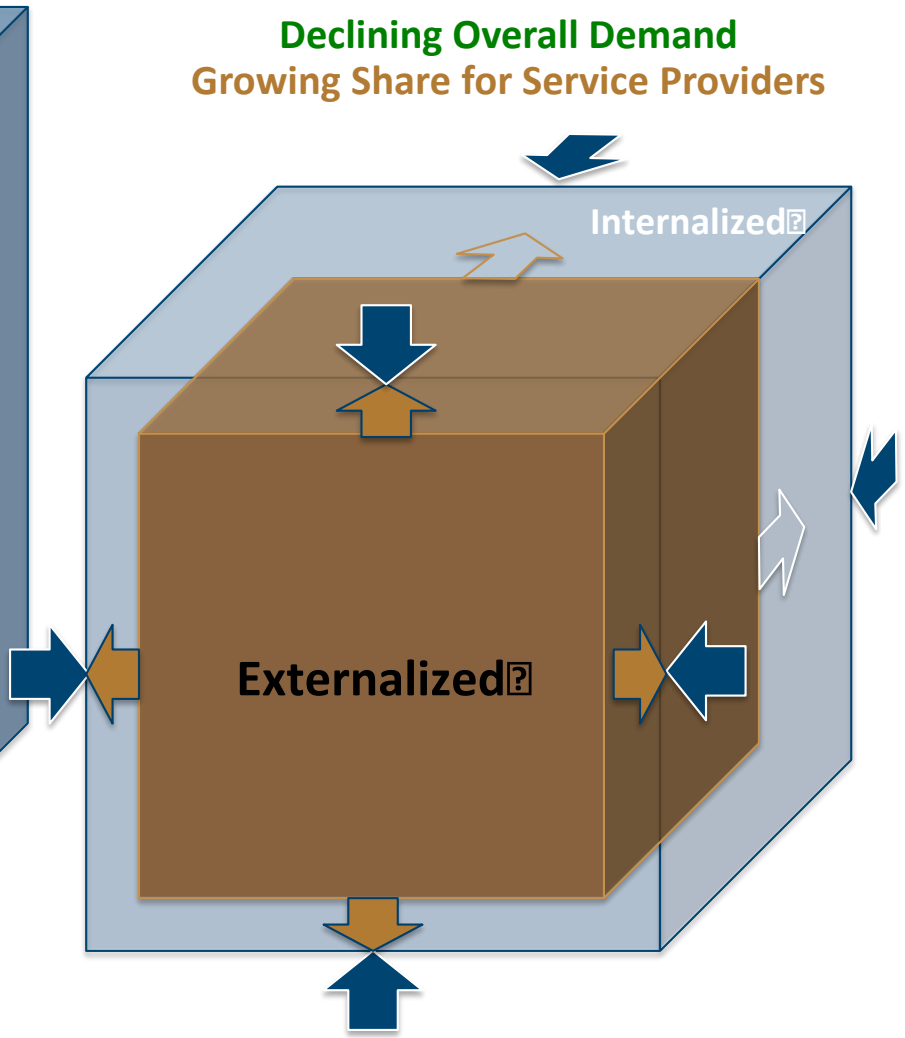
Declining Overall MOVE & DEPLOY Demand

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

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

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, 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

Questions, comments and ideas are most welcome

Georgia Tech's Physical Internet Lab