Georgia Tech Physical Internet Center
Stewart School of Industrial & Systems Engineering

PHYSICAL INTERNET ENABLED HYPERCONNECTED CITY LOGISTICS

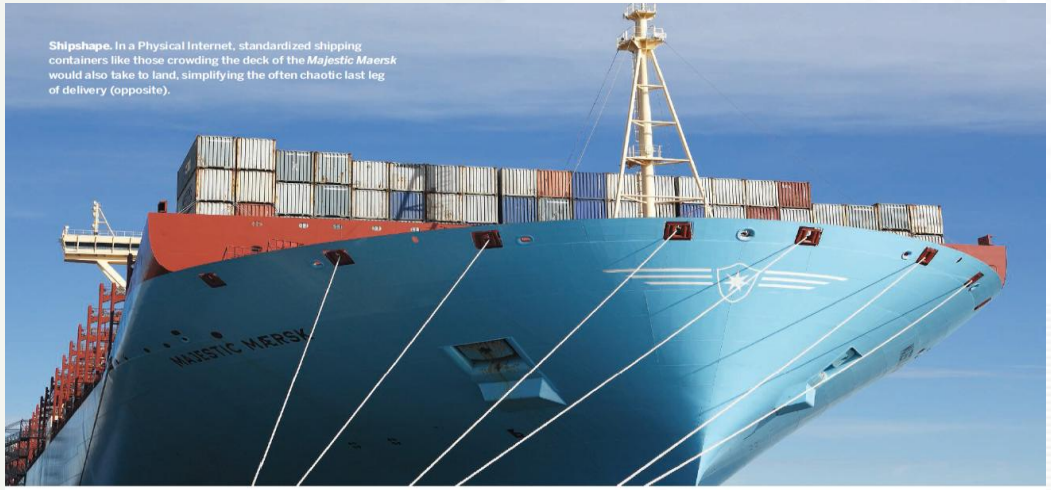
PROF. BENOIT MONTREUIL

COCA-COLA CHAIR IN MATERIAL HANDLING & DISTRIBUTION
PHYSICAL INTERNET CENTER
SUPPLY CHAIN & LOGISTICS INSTITUTE
SCHOOL OF INDUSTRIAL & SYSTEMS ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

CREATING THE NEXT®

Internet Metaphor Guiding Transformation to Next-Generation Logistics

Building a Physical Internet dealing with physical objects
Learning from the Digital Internet dealing with informational objects



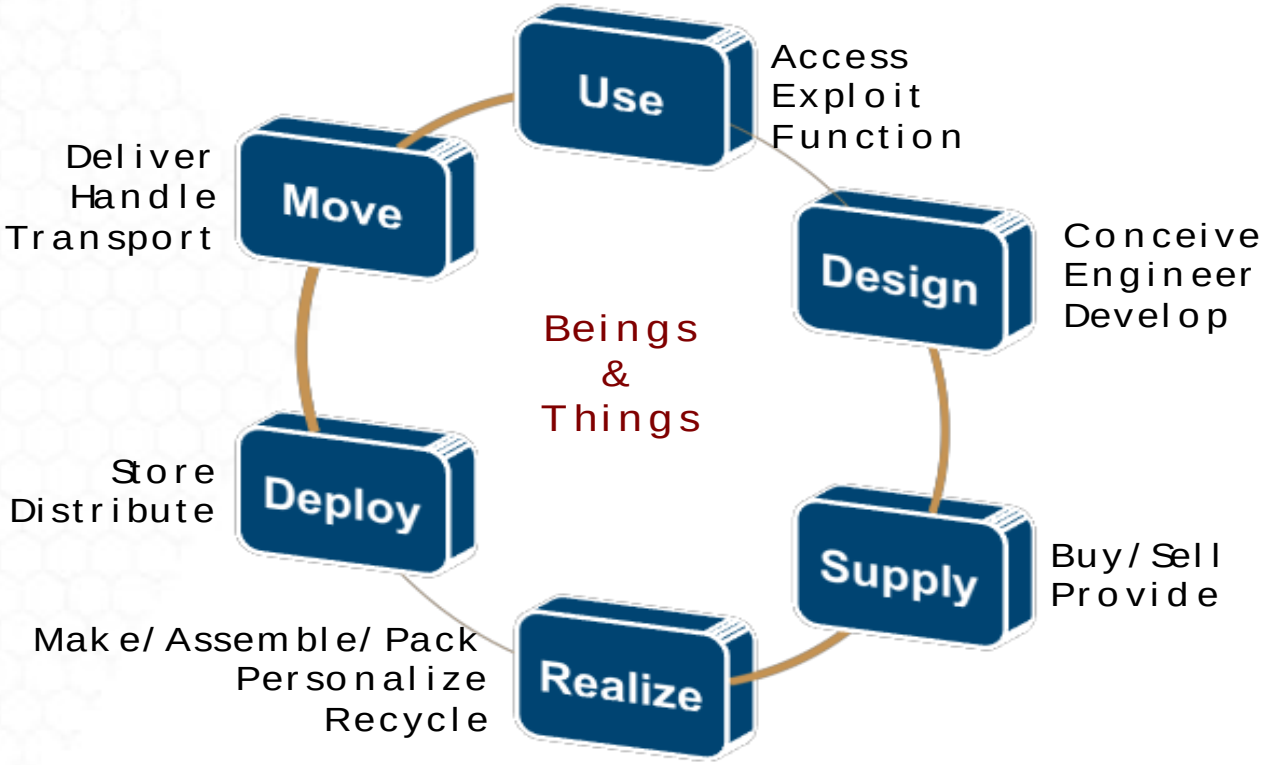
The information highway gets physical

The Physical Internet would move goods the way its namesake moves data

Science Magazine
June 6, 2014

Rethinking
the Global Supply Chain

Serving humanity's demand for physical object services



Montreuil B. (2011). *Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge*, **Logistics Research**, Vol. 3, No. 2-3, p. 71-87

Worldwide Next-Generation Logistics System: The Physical Internet

Hyperconnected global logistics system aiming to serve efficiently and sustainably

humanity's demand for physical object services

by enabling seamless open resource sharing and flow consolidation

through standardized encapsulation, modularization, protocols and interfaces

Image source: clyderathbone.com

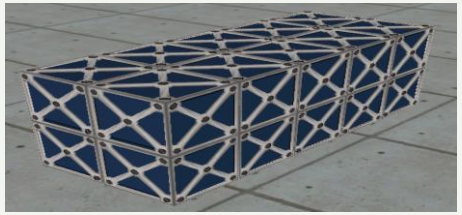
Hyperconnected:
Components and actors intensely interconnected on multiple layers, ultimately anytime, anywhere

Interconnectivity layers:
digital, physical, operational, business, legal and personal

Hyperconnected system definition by B. Montreuil, International Physical Internet Conference, Keynote Presentation, 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.

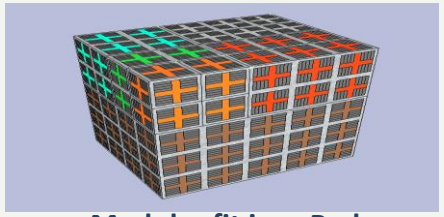
Physical Internet Building Blocks

Transport Containers (π-Pods)



Modular fit in π-certified vehicles
12; 6; 4,8; 3,6; 2,4; 1,2 meters

Handling Containers (π-Boxes)



Modular fit in π-Pods
1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1 – ε meters

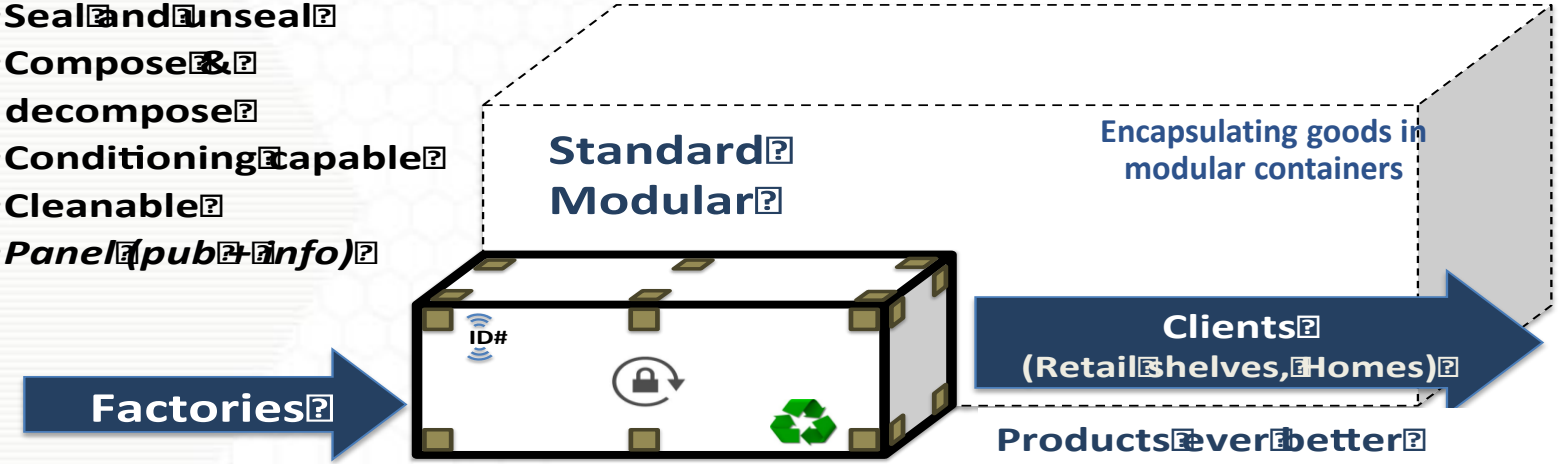
Packaging Containers (π-Packs)

Modular fit in π-Boxes
1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1 – ε - δ meters

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*

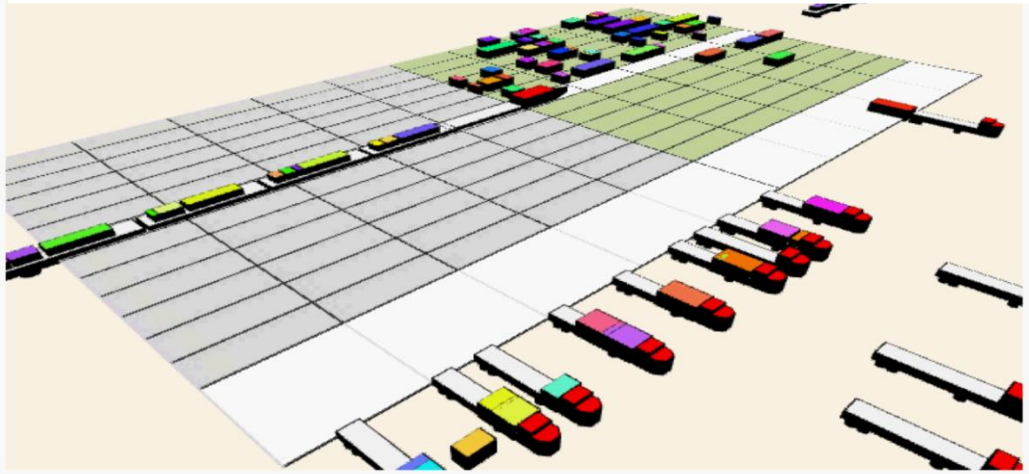
Eco-friendly
- Light & thin
- Reusable and/or recyclable
- Minimal off-service footprint
- Distinct structural grades



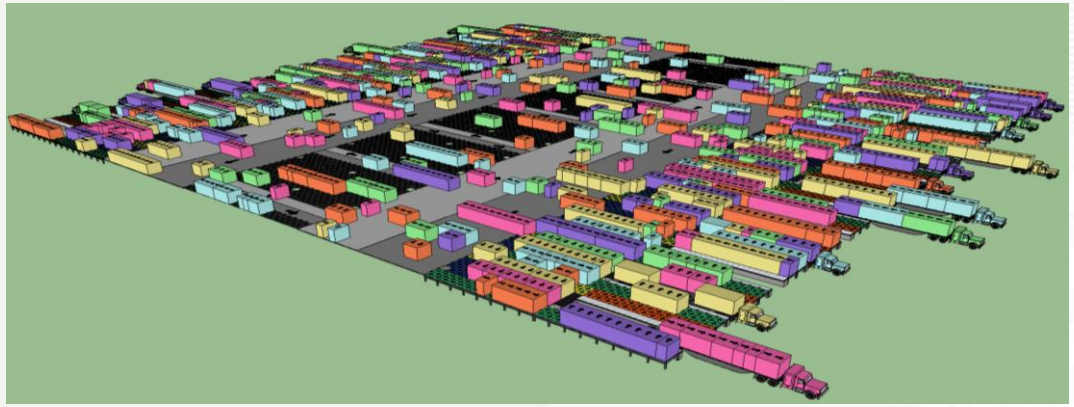
Unified Set of Standard Modular Logistics Containers

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.

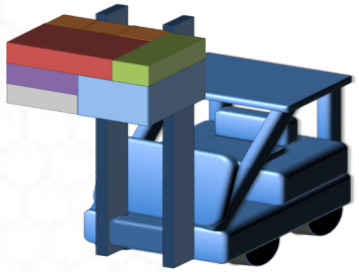
Physical Internet Building Blocks



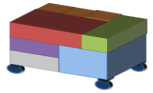
Road-Rail Transshipment Hub

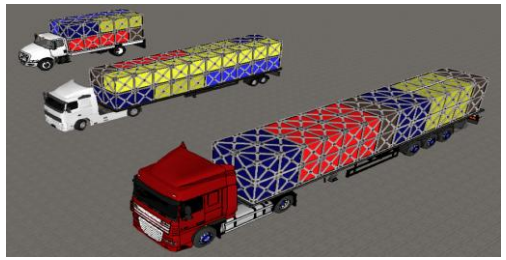


Road-Based Crossdocking Hub

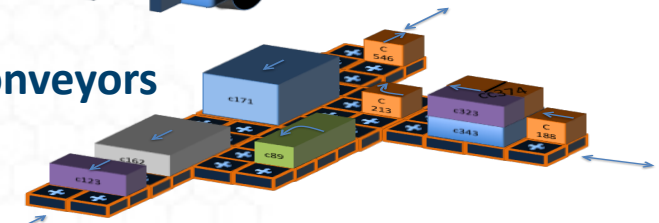


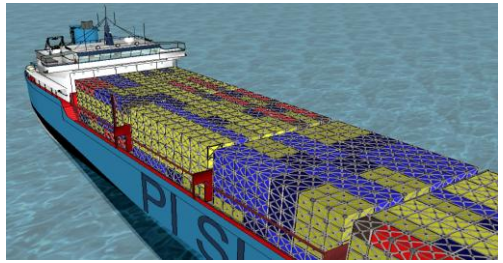
π-movers



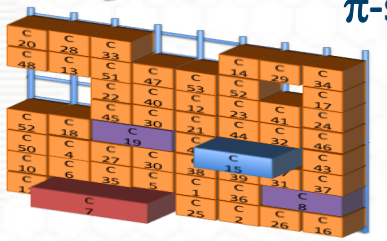


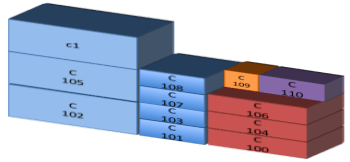
π-conveyors

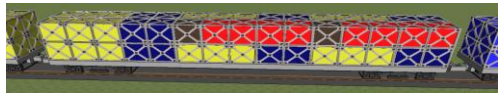




π-stores







Certified Open Logistics Facilities and Ways

Containerized Logistics Equipment and Technology

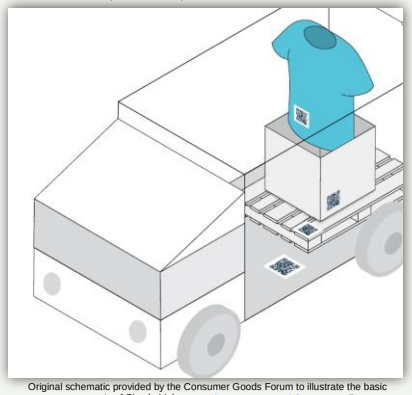
Unified Set of Standard Modular Logistics Containers

Reference: Montreuil, B., R.D. Meller, E. Ballot (2010) *Towards a physical internet: the impact on logistics facilities and material handling systems design and innovation*, in Progress in Material Handling Research, Edited by K. Gue et al., Material Handling Industry of America, 23 p., 2010.

Physical Internet Building Blocks

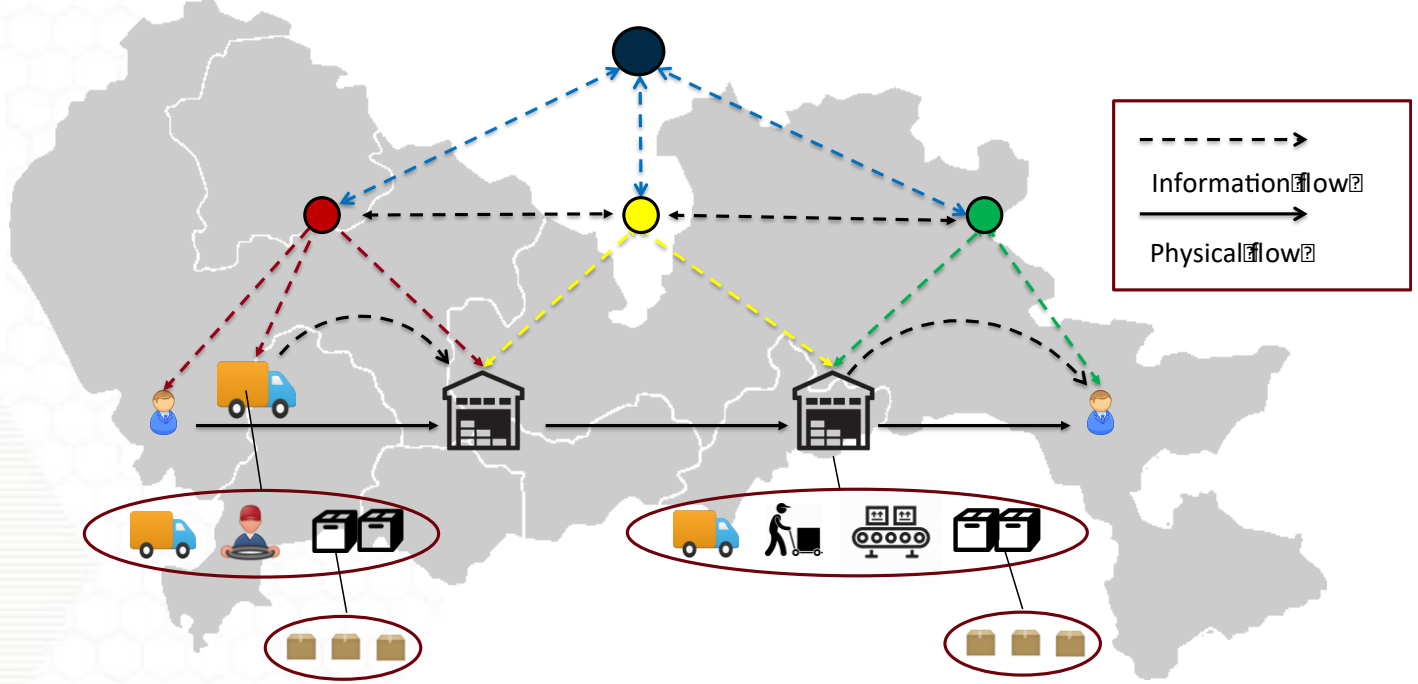
Enabling Seamless, Trustworthy, Ubiquitous Monitoring, Traceability and Transactions

We here adapt to hyperconnected parcel logistics the Simple Links concept recently introduced by the Consumer Goods Forum



Original schematic provided by the Consumer Goods Forum to illustrate the basic concepts of Simple Links: www.theconsumergoodsforum.com

Schematics provided by the Consumer Goods Forum
www.theconsumergoodsforum.com



Simple Links

Internet-of-Things

BlockChain

Open Logistics Decisional & Transactional Platforms

Standard Logistics Protocols

Global Logistics Monitoring System

Containerized Logistics Equipment and Technology

Certified Open Logistics Facilities and Ways

Unified Set of Standard Modular Logistics Containers

Physical Internet Building Blocks

Apps and Situation Room by Elementum.com
Georgia Tech's Physical Internet Lab

Smart Data-Driven Analytics, Optimization & Simulation

Open Logistics Decisional & Transactional Platforms

Global Logistics Monitoring System

Certified Open Logistics Facilities and Ways

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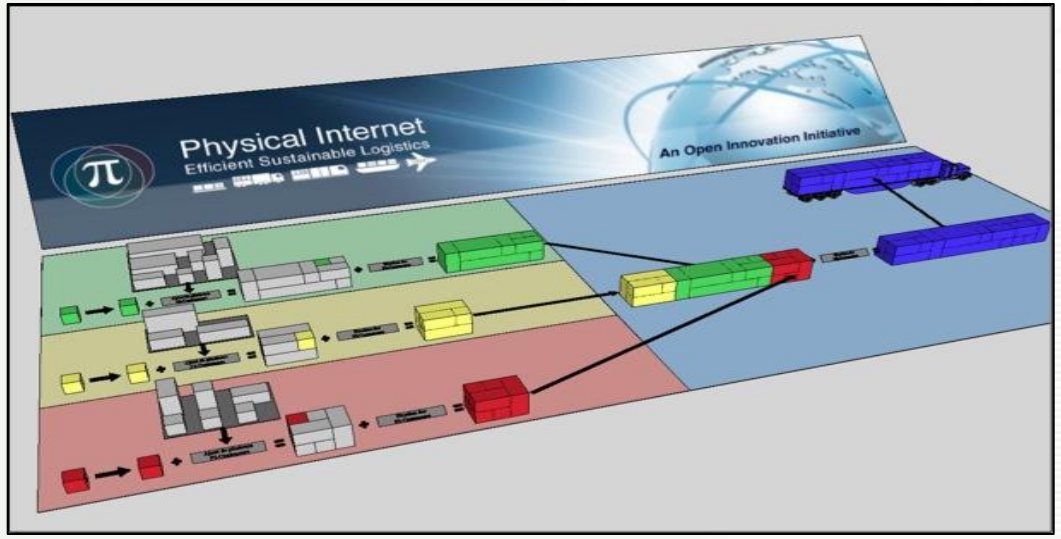
Physical Internet Building Blocks



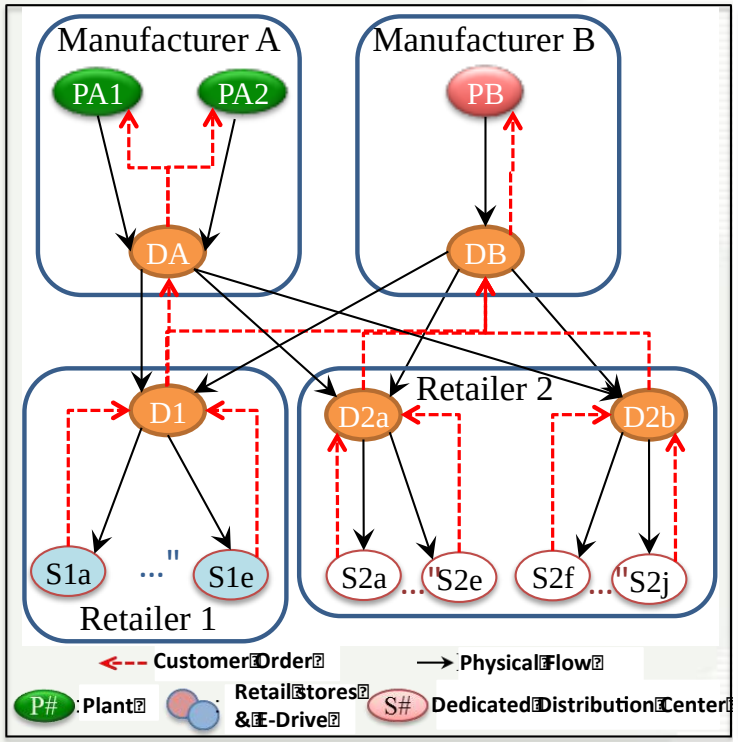
B. Montreuil & C. Thivierge, 2011

Enabling Efficient, Sustainable, Smart, Agile, Adaptable, Scalable, Resilient, Hyperconnected Supply Chains

- Certified Open Logistics Service Providers
- Smart Data-Driven Analytics, Optimization & Simulation
- 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

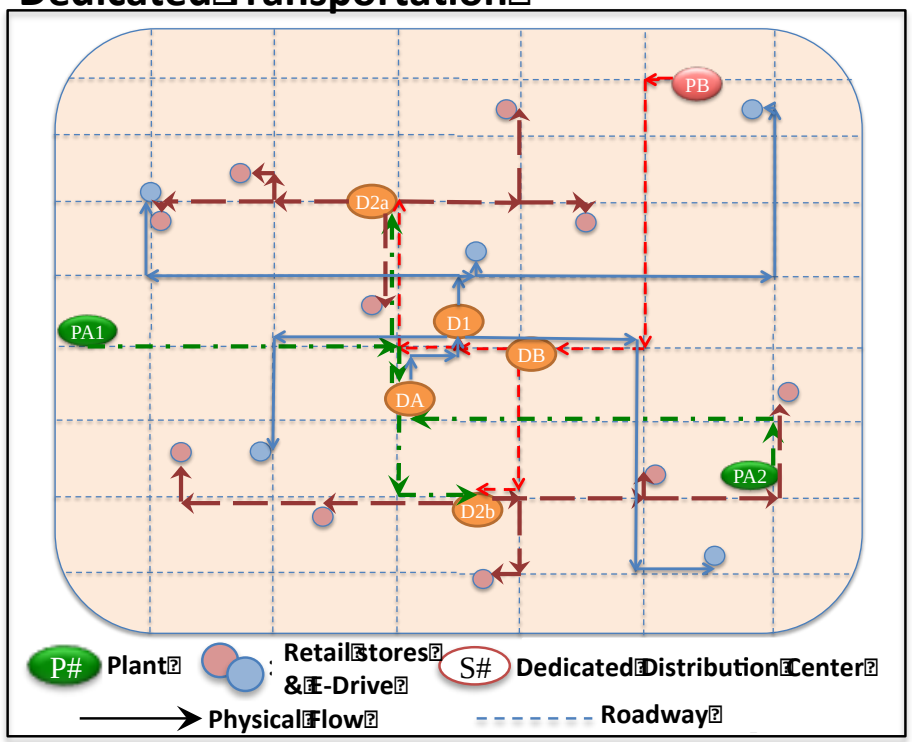
Logistics Infrastructure: Shared assets enabling logistics to support supply chains

Hyperconnected Transportation: A Simple Case

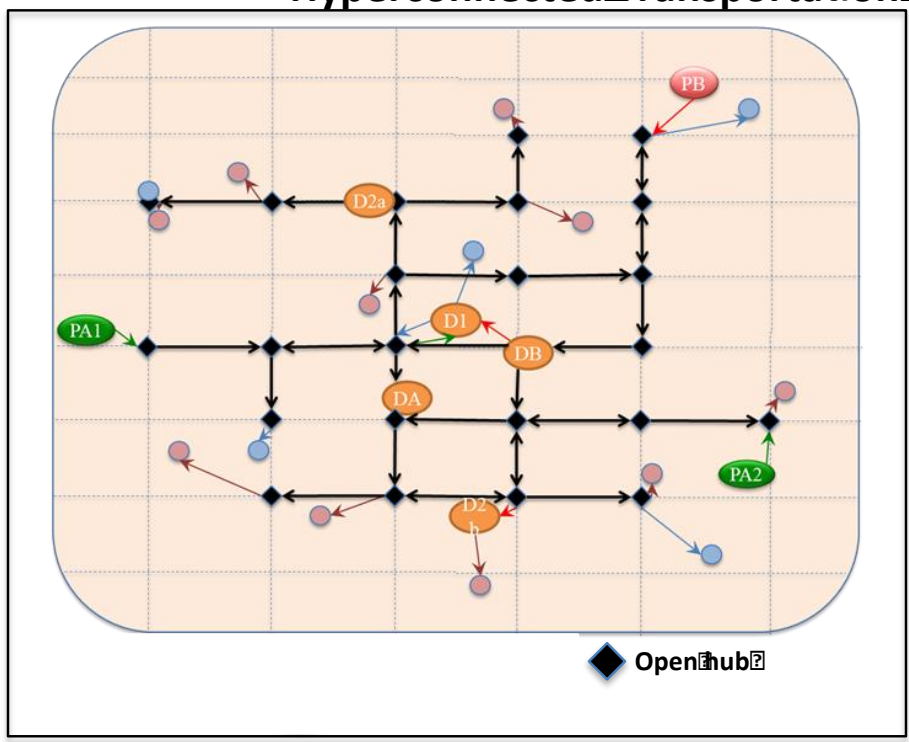


Current Conceptual Networks

Dedicated Transportation



Hyperconnected Transportation

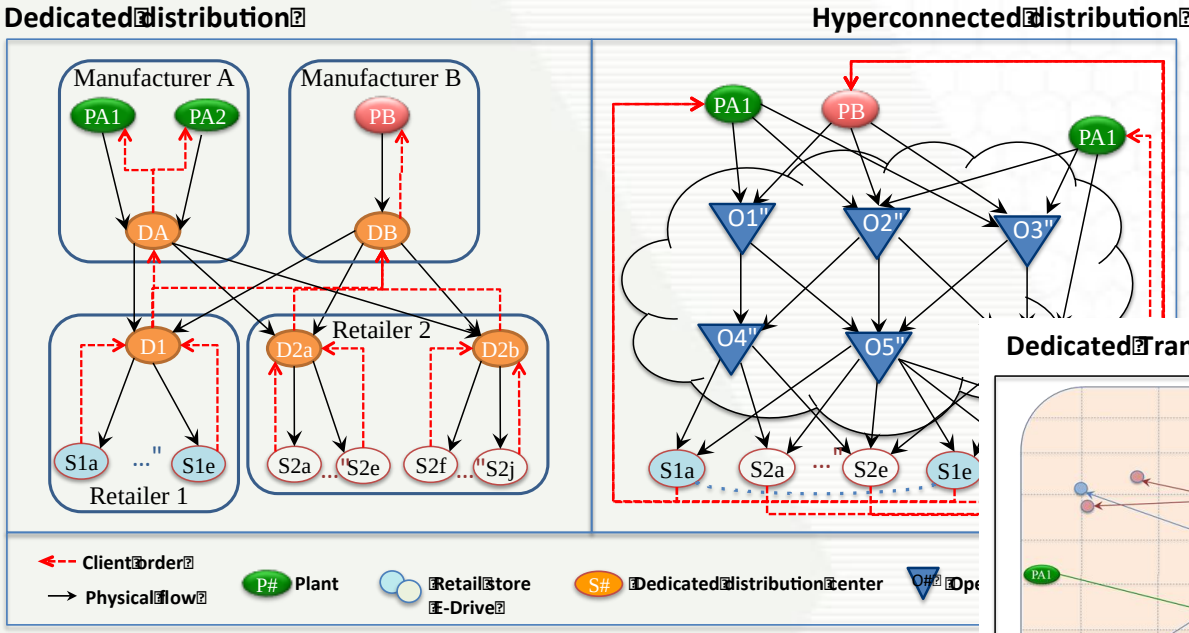


Current Spatial Flows

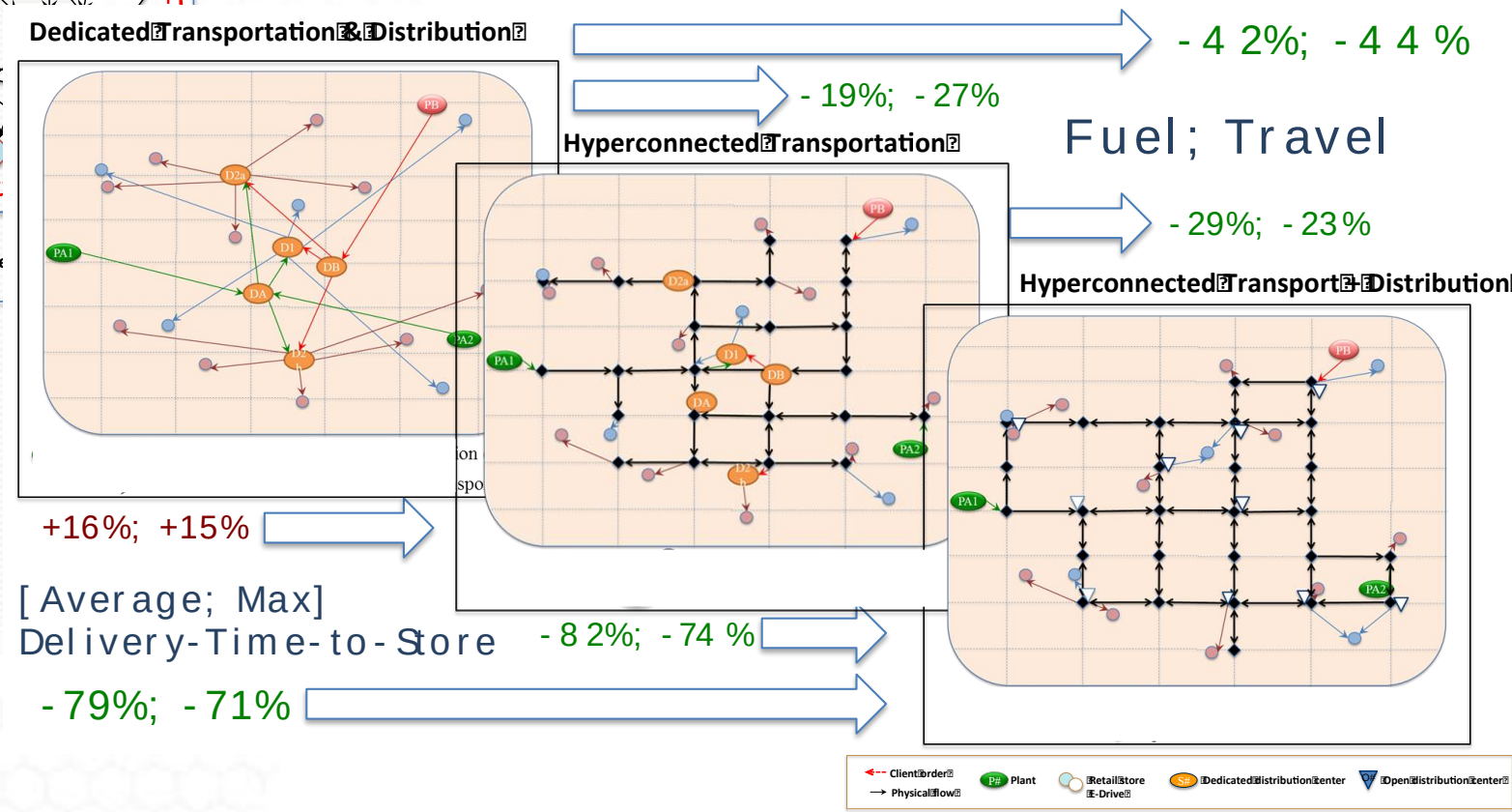
Travelled distance: -27%
Fuel Consumption: -19%
Average delivery time: +2%
Maximum delivery time: -36%

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: A Simple Case



Transposing Cloud Storage & Computing Concepts, Practices & Business Models from IT to Logistics and Supply Chains

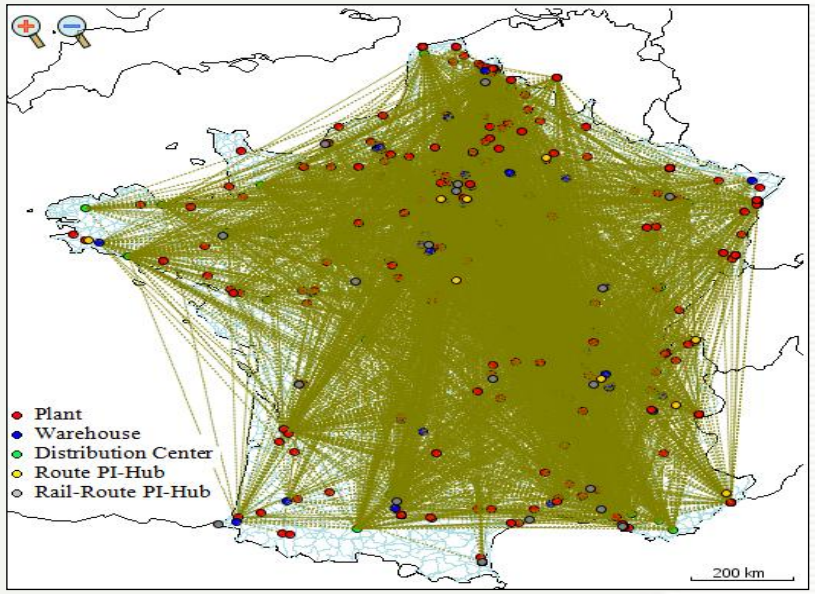


Adapted from: Hakimi D., B. Montreuil & E. Ballot (2012), Simulating a Physical Internet Enabled Logistics Web: the Case of Mass Distribution in France, ISERC 2012, 2012/5/19-23

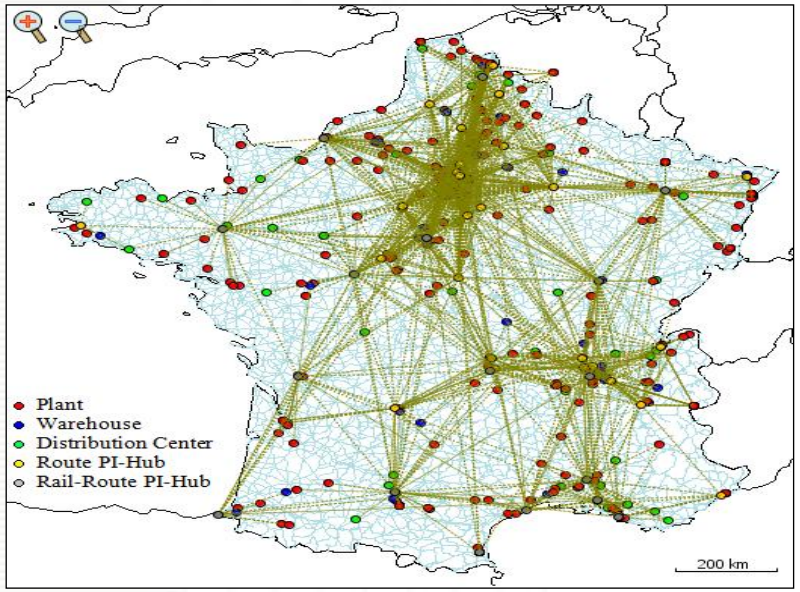
Hyperconnected Transportation: Large Scale Experiment in France

Simulation Experiment with Top Retailers Carrefour & Casino and their top 100 suppliers

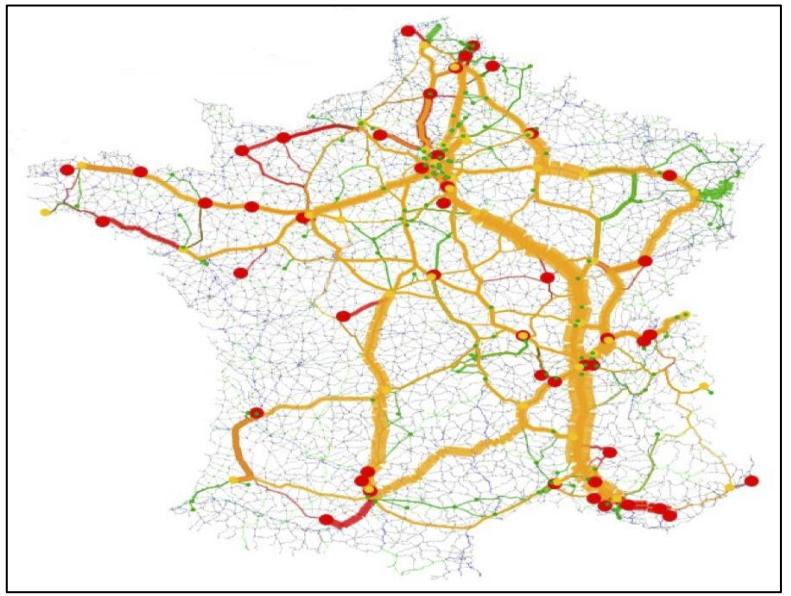
Modular Container; Open Crossdocking Hubs; Multimodal, Multi-Party, Inter-Hub Routing



Current flows



Hyperconnected flows



Current: Trucks
Hyperconnected: Trucks & Rail

Economical: Up to 32% overall cost saving

Environmental: About 60% reduction of greenhouse gas emissions

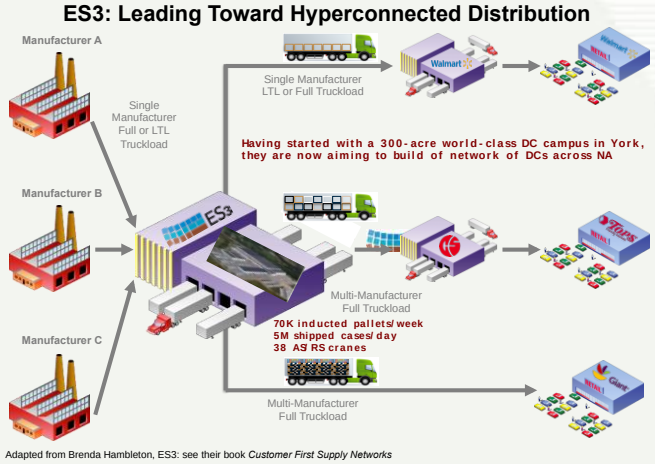
Truckers return home every day: Helping reduce trucker turnover and shortage

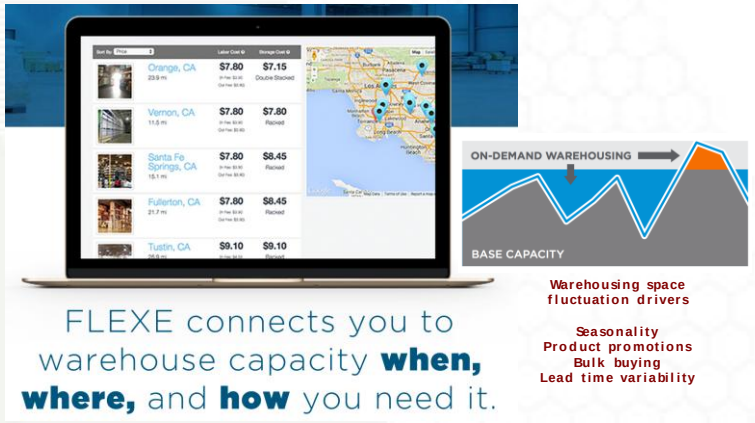
Project lead by E. Ballot, B. Montreuil & R. Glardon: PREDIT Best International Project
Ballot É., B. Montreuil, R. Meller (2015), The Physical Internet: The Network of Logistics Networks, Documentation Française.

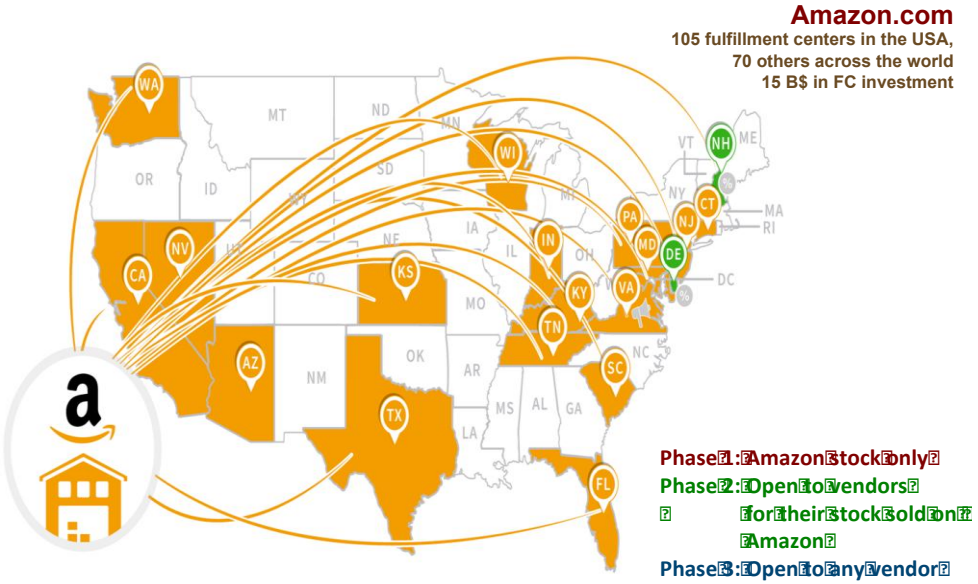
Hyperconnected Distribution & Fulfillment: Current Large-Scale Models

Dynamically deploying products for rapid on-demand fulfillment

Exploiting Physical Internet principles, Beyond client dedicated facilities and services







The ES3 Model

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

The ES3 Model

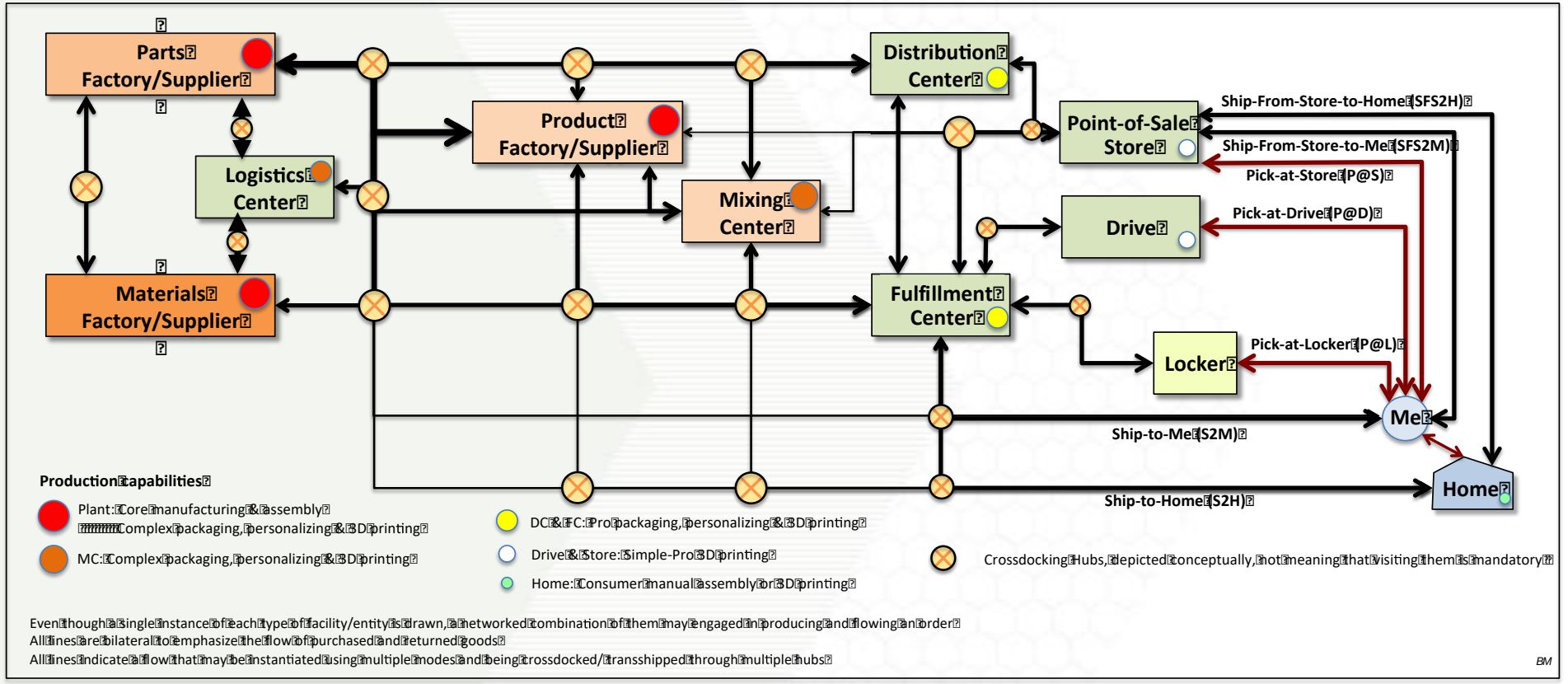
On-Demand Warehousing
Asset-free platform
Multi-warehouse, Multi-User
AirBnB-like shared economy model
Pay-per-Use

The Fulfillment-By-Amazon Model

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

Towards Smart Hyperconnected Omnichannel Logistics and Supply

Hundred of thousands of suppliers, distributors & (e-)retailers
Millions of facilities and vehicles, billions of customers



Blurred Facility Roles

A Web of Hyperconnected Facilities, Modes and Actors

Expected Delivery or Pickup with Minutes, Hours, maybe a few Days
With Minimal Stock Smartly Flowed and Deployed Between Suppliers and Customers

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.
CMO Innovation, 2015-09-02, http://www.enterpriseinnovation.net/sponsor-article/art-and-science-omni-channel-retailing http://www.wilsonperumal.com/blog/can-97-of-retailers-be-wrong-about-omni-channel-commerce/

City Logistics: Its Main Goals

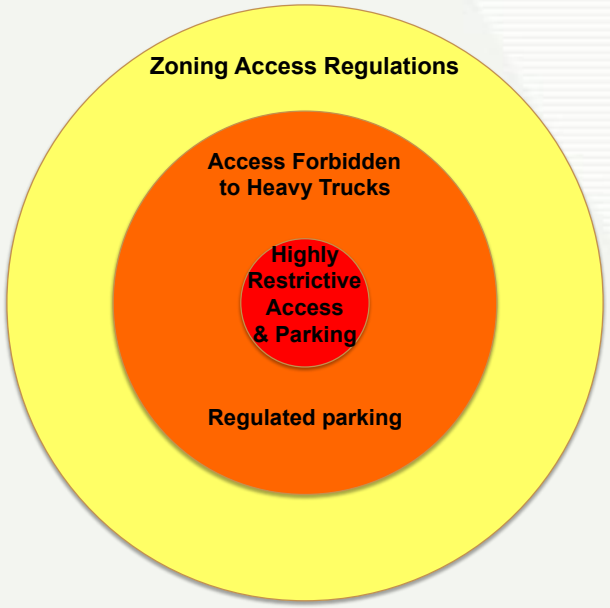
To reduce the negative impact of freight-vehicle movements on city-living conditions, particularly in terms of congestion/mobility and environmental impact, while not penalizing its social and economic activities and fostering an efficient and sustainable transportation system
(e.g., Taniguchi *et al.* 2003, 2013)

- **To reduce and control the urban presence and motorization of freight vehicles**
- **To improve the efficiency of freight movements & their environmental footprint**
- **To reduce the number of empty vehicles getting in, through and out of the city**

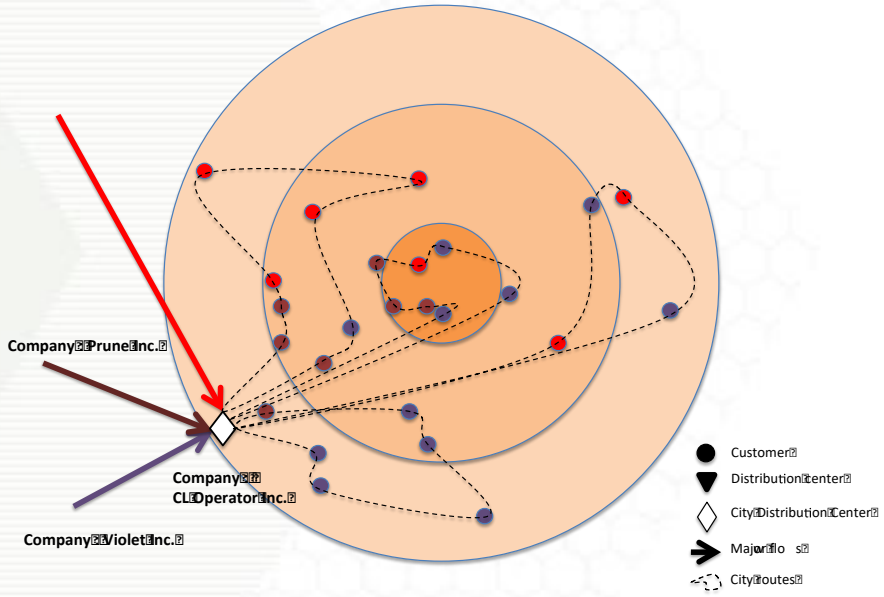
(e.g. Benjelloun et al., 2010, Dablanc, 2007)

City Logistics Concepts

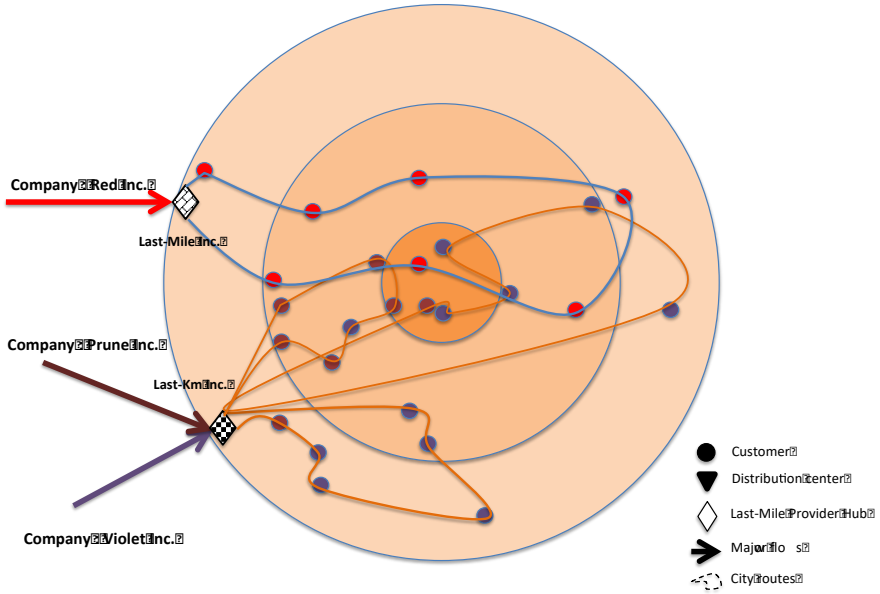
Access and Parking Regulations



City Distribution Center



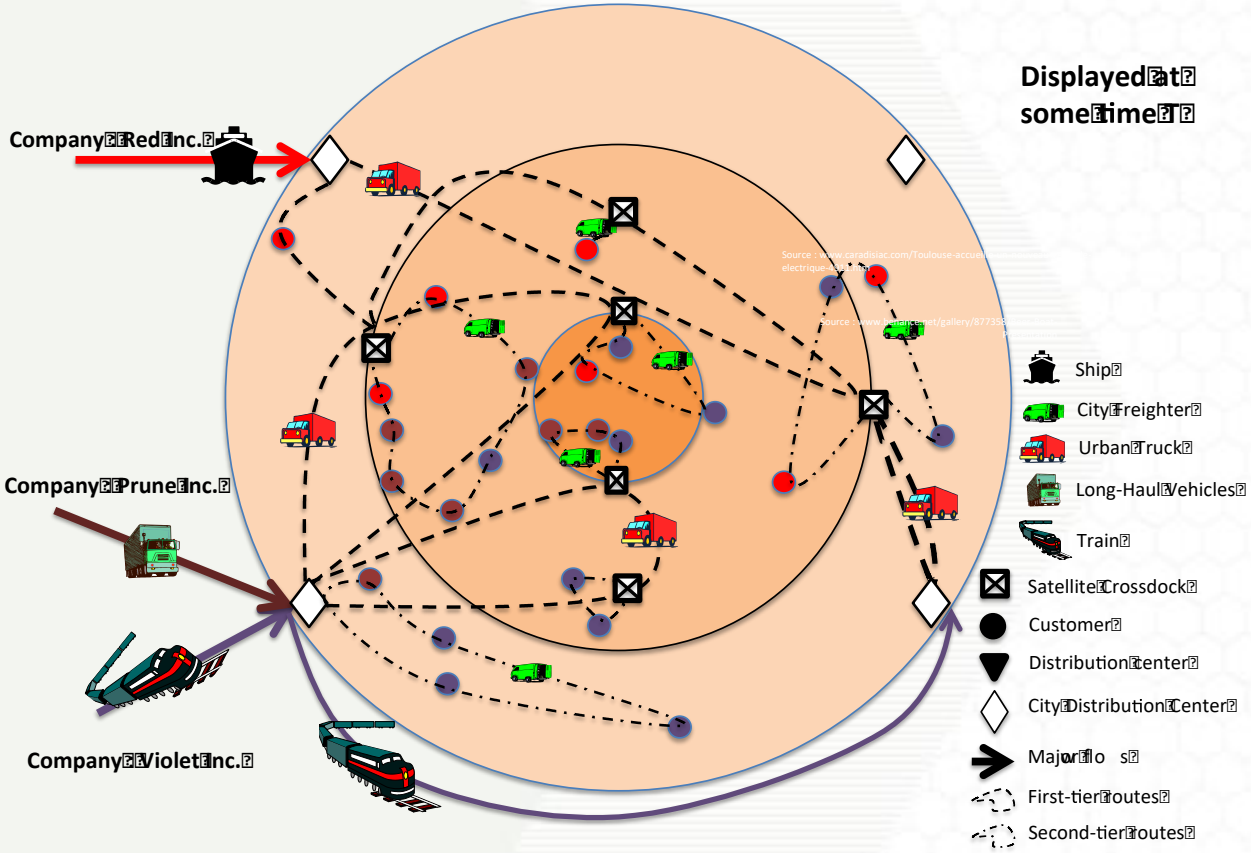
Last-Mile Delivery Service Providers



Adapted from: T. G. Crainic and B. Montreuil, Physical internet enabled Hyperconnected City logistics," Transportation Research Procedia, vol. 12, pp. 383-398., 2016.

City Logistics Concepts

Two-Tier Hub & Satellite Network



Tier-Adapted Ecofriendly Vehicles

Mostly smaller, green, active or electrical vehicles

Adapted from: T. G. Crainic and B. Montreuil, Physical internet enabled Hyperconnected City logistics," Transportation Research Procedia, vol. 12, pp. 383-398., 2016.

Physical Internet Enabled City Logistics

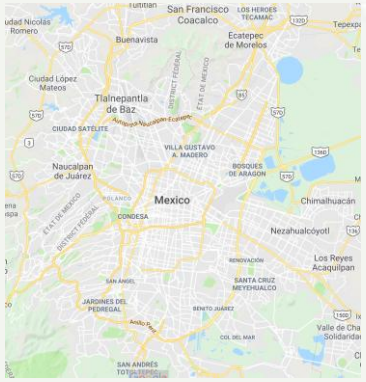
Core Hyperconnected City Logistics Concepts		
Interconnect	Cities as Nodes of the World's Logistics Web	1
	Cities by Systems Standardization	2
	The Multi-Faceted Activities of City Logistics	3
	City Logistic Networks in a City Web Architecture	4
	The Multiplicity of Urban Logistics Centers	5
	City Logistics Stakeholders into an Open System	6
	Goods Through Modular Logistics Containers	7
	People Mobility and Freight Logistics in the City	8
	City Logistics with Urban Planning	9

Interconnect Cities as Nodes of the World's Logistics Web

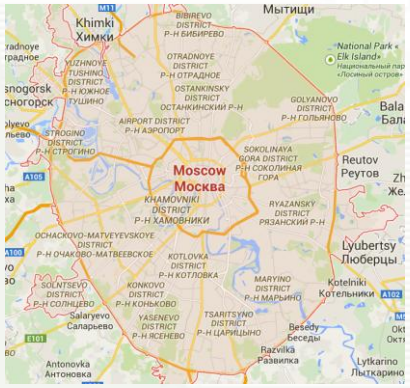
- Do not focus only on the city by itself
- Inter-City Flows: inbound and outbound

Interconnect Cities by Worldwide Systemic Standardization

Mexico

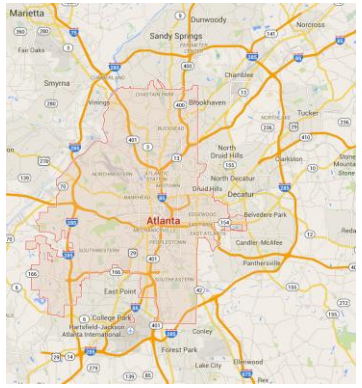


Moscow

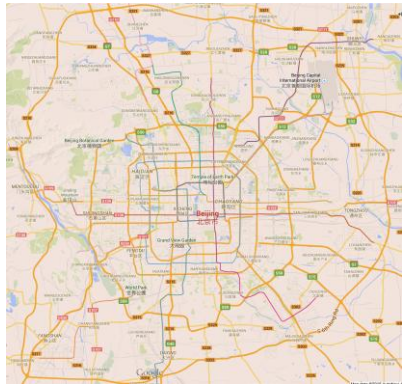


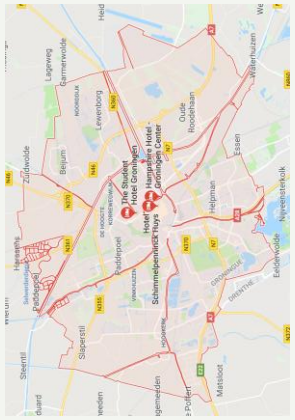
Paris

Atlanta

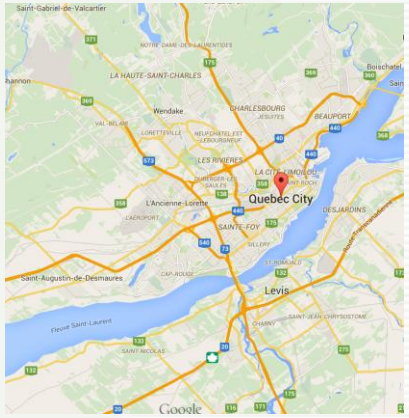


Beijing

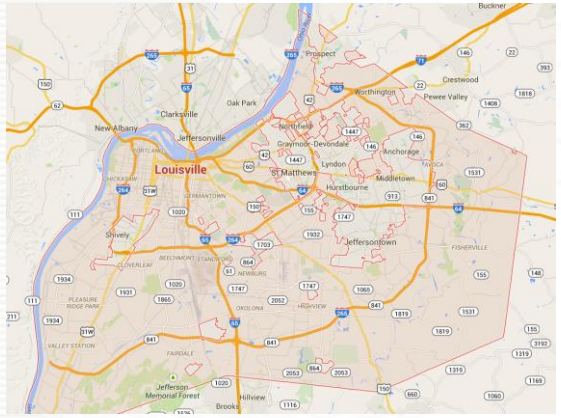




Groningen



Québec



Louisville

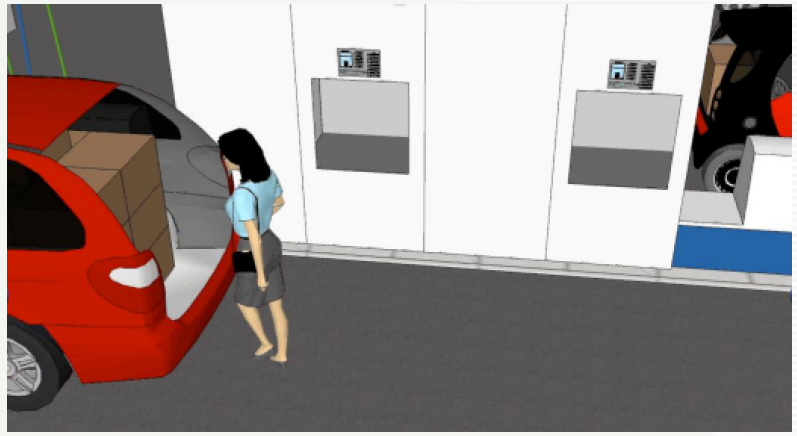
Bordeaux

Porto

Each city thinks it is unique and requires custom logistics solutions,
yet the last thing large retailers, e-tailers, manufacturers and the likes want
is for each city to have distinct interfaces and protocols

Exploiting Hyperconnected On Demand Crowdsourced Delivery

People carrying modular containers between hubs using public transit, bicycles, cars, vans



Exploiting smartphone-based apps; Pickup packs at hub near departure

Deliver them at hub near arrival, making money; Others carry them in relay mode to destination

Interconnect People Mobility & Freight Logistics Into, Within and Out of City

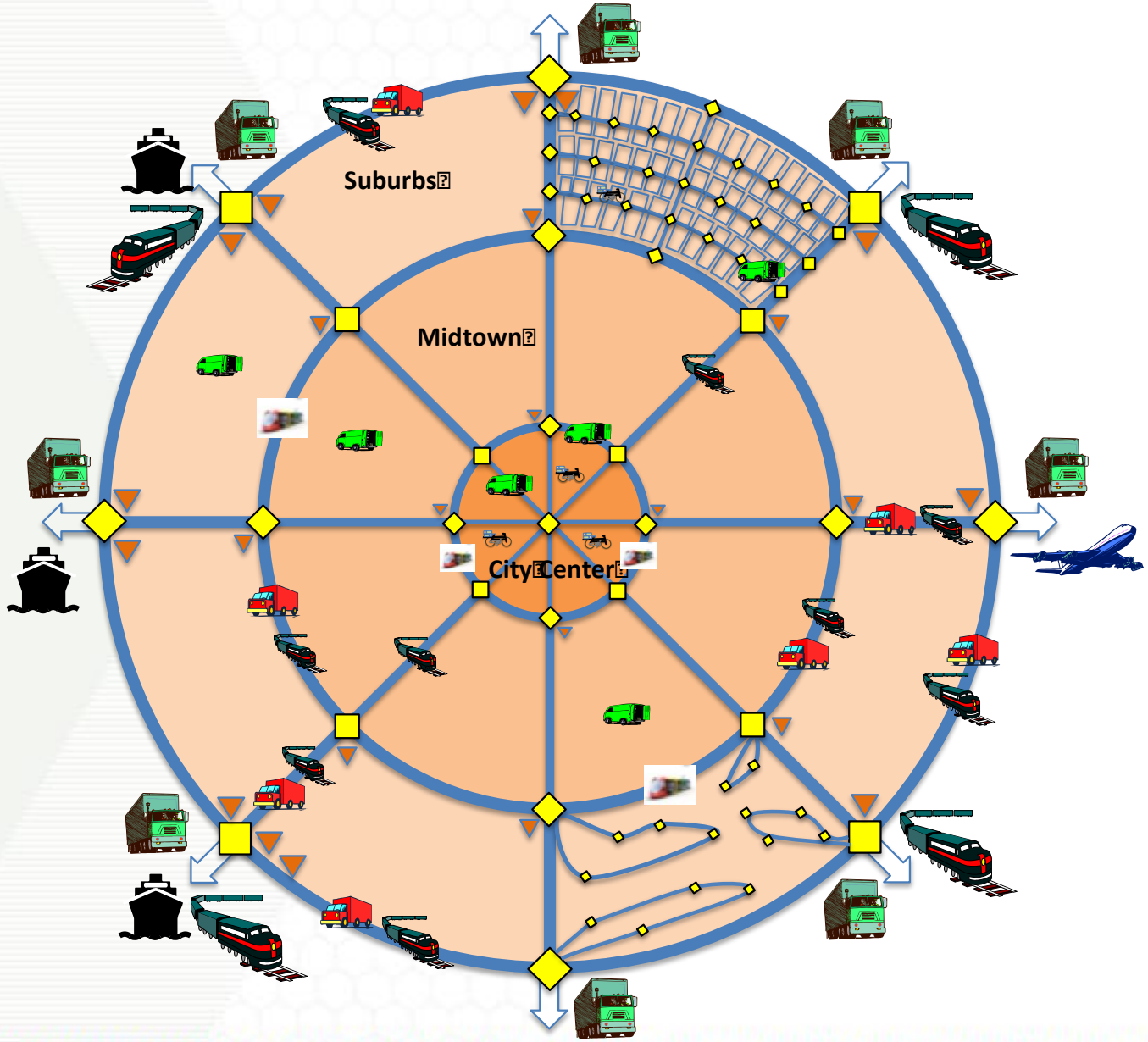
Source : www.traconference.eu/papers/pdfs/TRA2014_Fom_29372.pdf

Source : www.boldride.com/ride/2014/uniblock-by-jungu-lee

Slide adapted from Durand A, N. Lavigne-Lefebvre, J.-F. Rougès, M. Carrier, C. Gagné, J. Mercier, B. Montreuil (2014), L'Électrificaition des Transports: Une Perspecitive québécoise, ITIS Research Report, Universiité Laval, Québec, Canada

Hyperconnected City Logistics: Developing Urban Logistic Intranet

- Bicycle, scooter, drone
- Urban transporter, personal vehicle
- Tramway, light rail, metrobus, barge
- Urban truck
- Long-distance vehicle
- Train
- Ship
- Plane, airship
- Urban hub
- Open DC



Exploiting most zone-appropriate π-container transport, handling & storage modes, vehicles, means & facilities

Building on synergies between freight logistics and people mobility

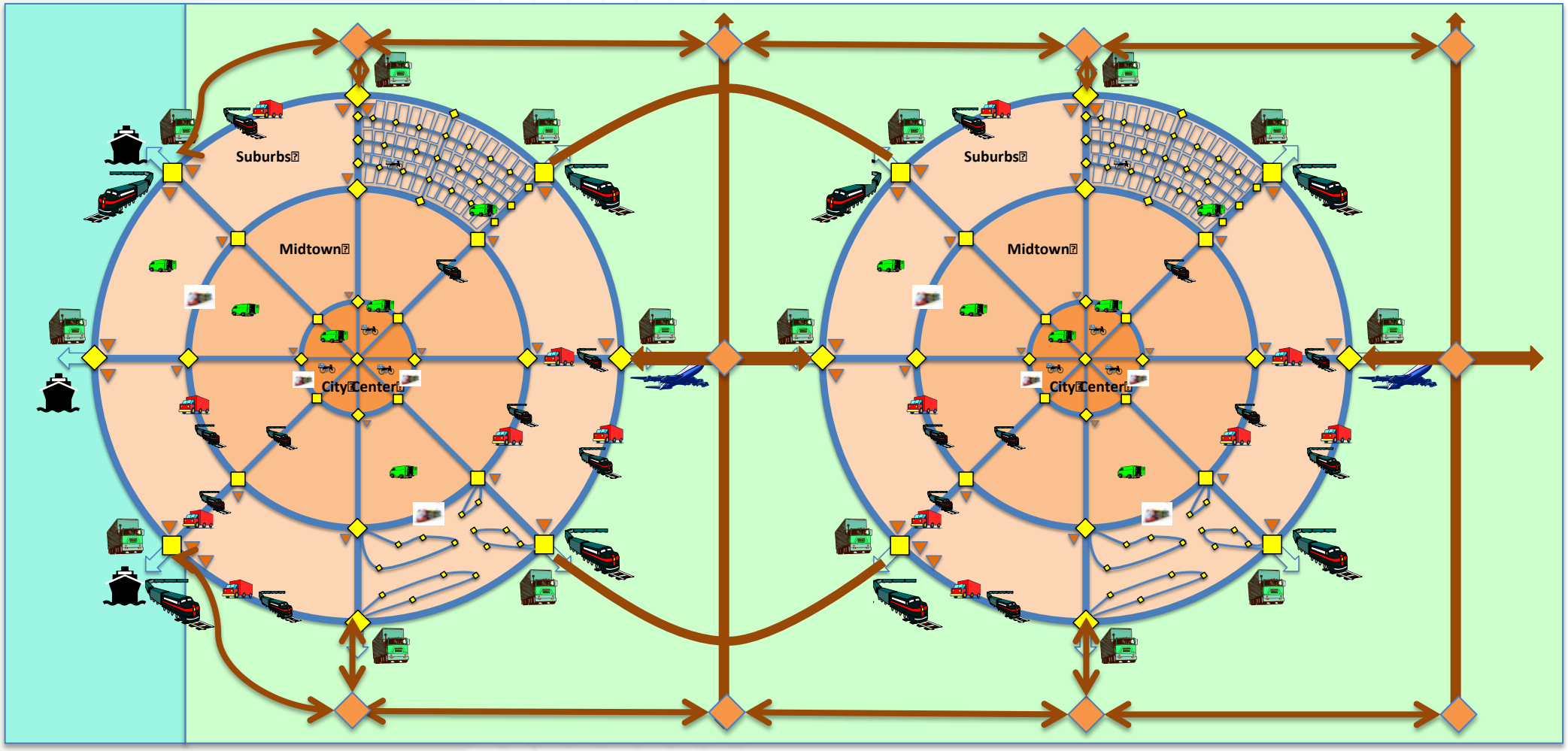
Aiming for gains in economic, environmental and societal efficiency, sustainability and service capability

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

Adapted from: T. G. Crainic and B. Montreuil, "Physical internet enabled Hyperconnected City logistics," Transportation Research Procedia, vol. 12, pp. 383-398., 2016.

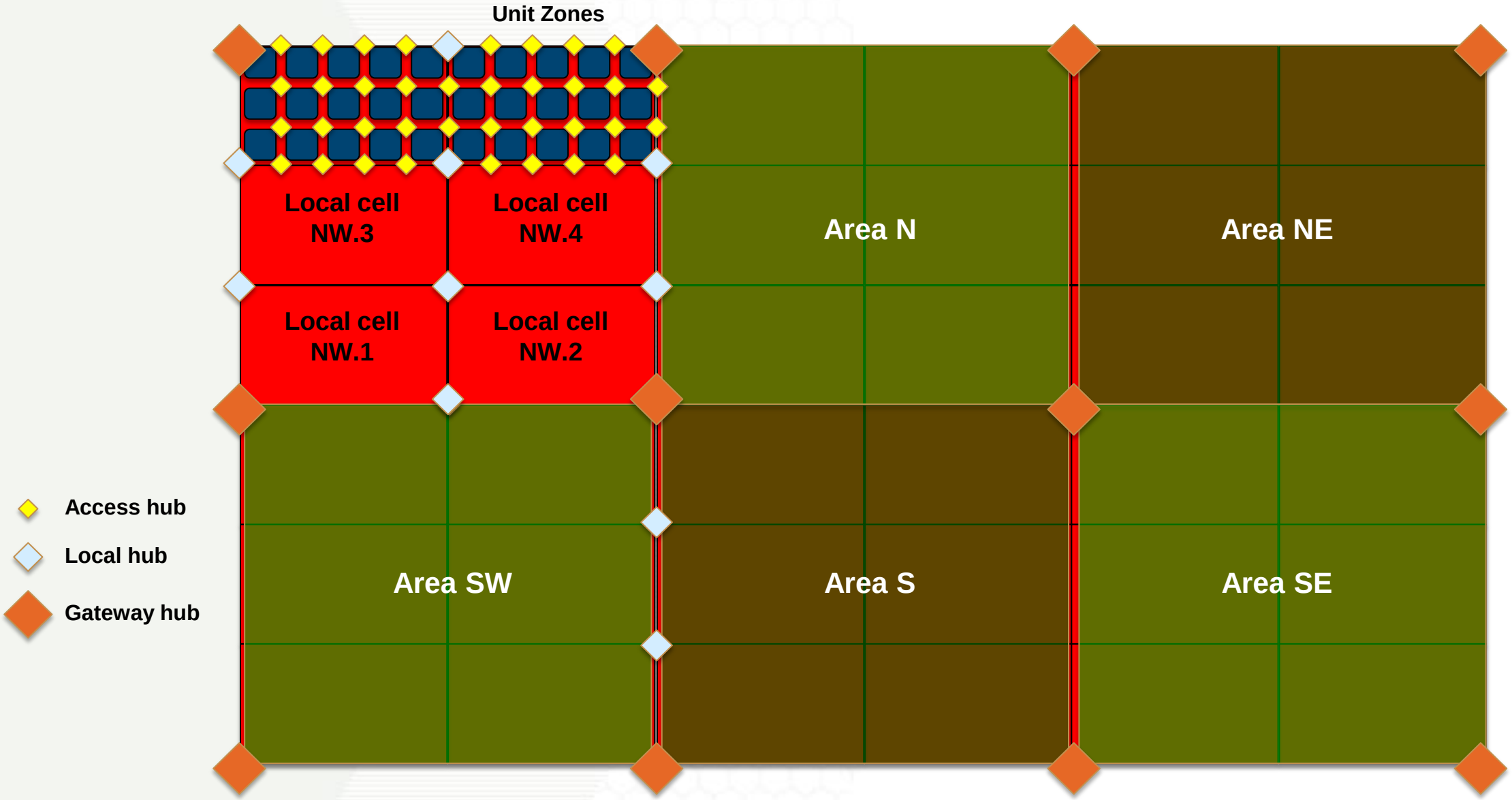
Interconnecting Cities

Economic, Environmental, Societal Sustainability, Development and Innovation



Numerous Stakeholders: At the Core, Citizens (Quality of Life, Jobs, …), Businesses (Ease to Do Business, …), Logistics Hubs (Near & Far, Ease to Connect)

Hyperconnected City Logistics: Urban Pixelization + Meshed Hub Networks



B. Montreuil et al., "Urban Parcel Logistics Hub and Network Design: The Impact of Modularity and Hyperconnectivity", Proceedings of IMHRC 2018, to appear., 2018

Hyperconnected City Logistics: Multi-Plane Urban Logistics Web

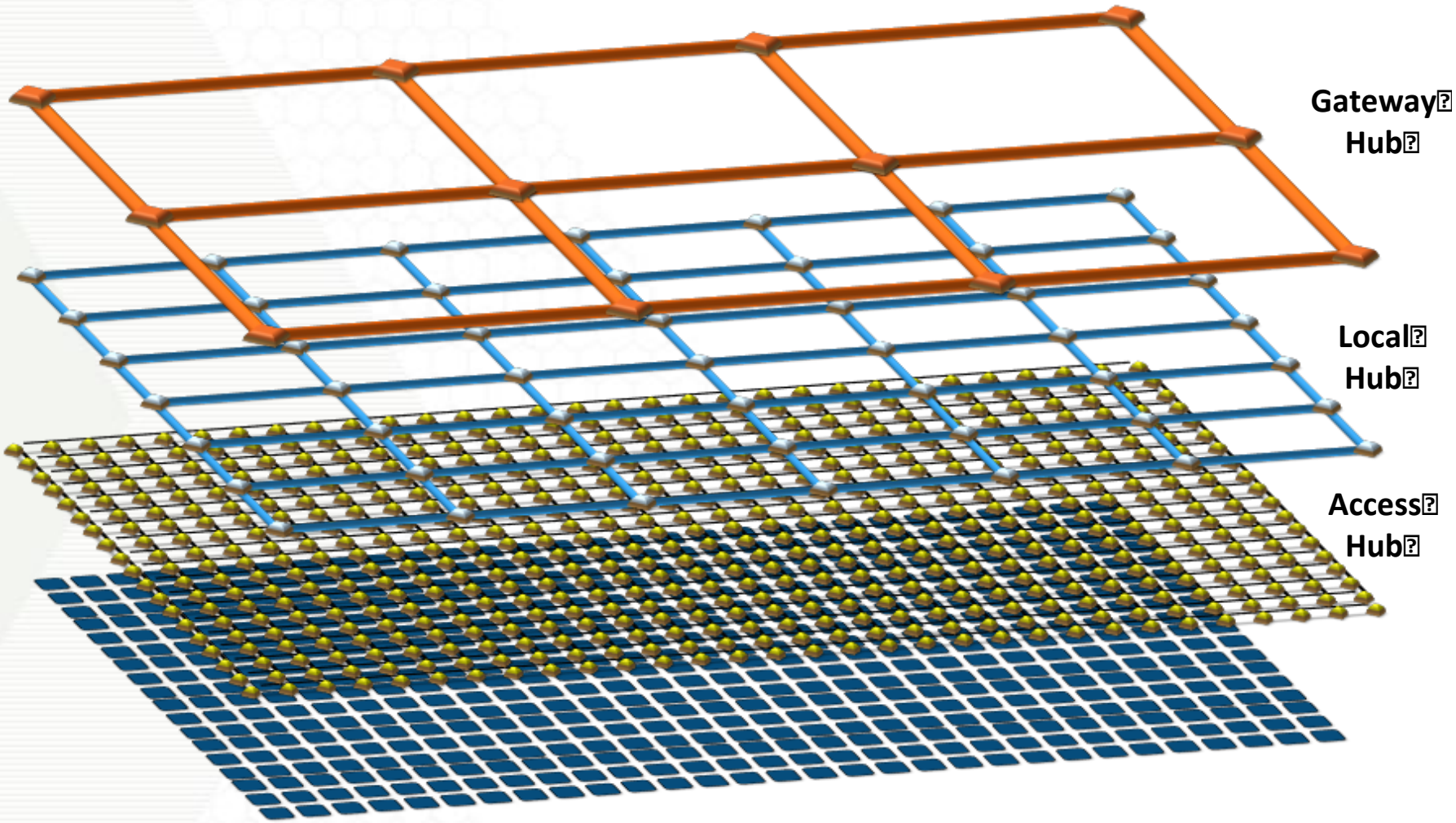
Interconnected Meshed Hub Networks for Fast, Precise, Efficient, Reliable Delivery

Plane 3
Inter-Area Network
Linking areas through gateway hubs

Plane 2
Inter-Cell Network
Linking local cells through local hubs

Plane 1
Inter-Zone Network
Linking unit zones through access hubs

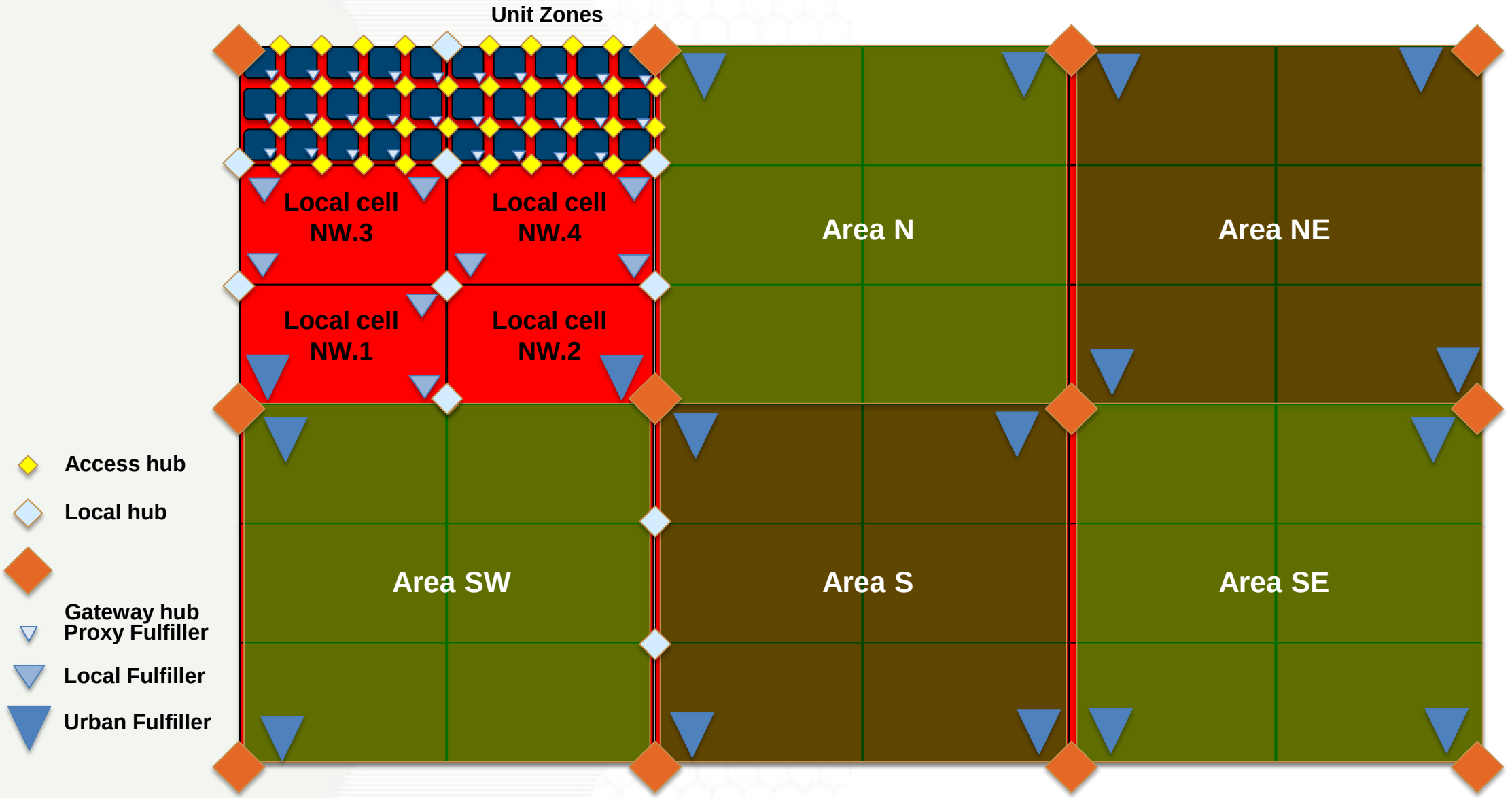
Plane 0
Inter-P/D Network
Linking Pickup/Delivery locations



The meshed networks of adjacent planes are connected by inter-hub links

Hyperconnected City Logistics: Meshed Hub & Fulfiller Networks

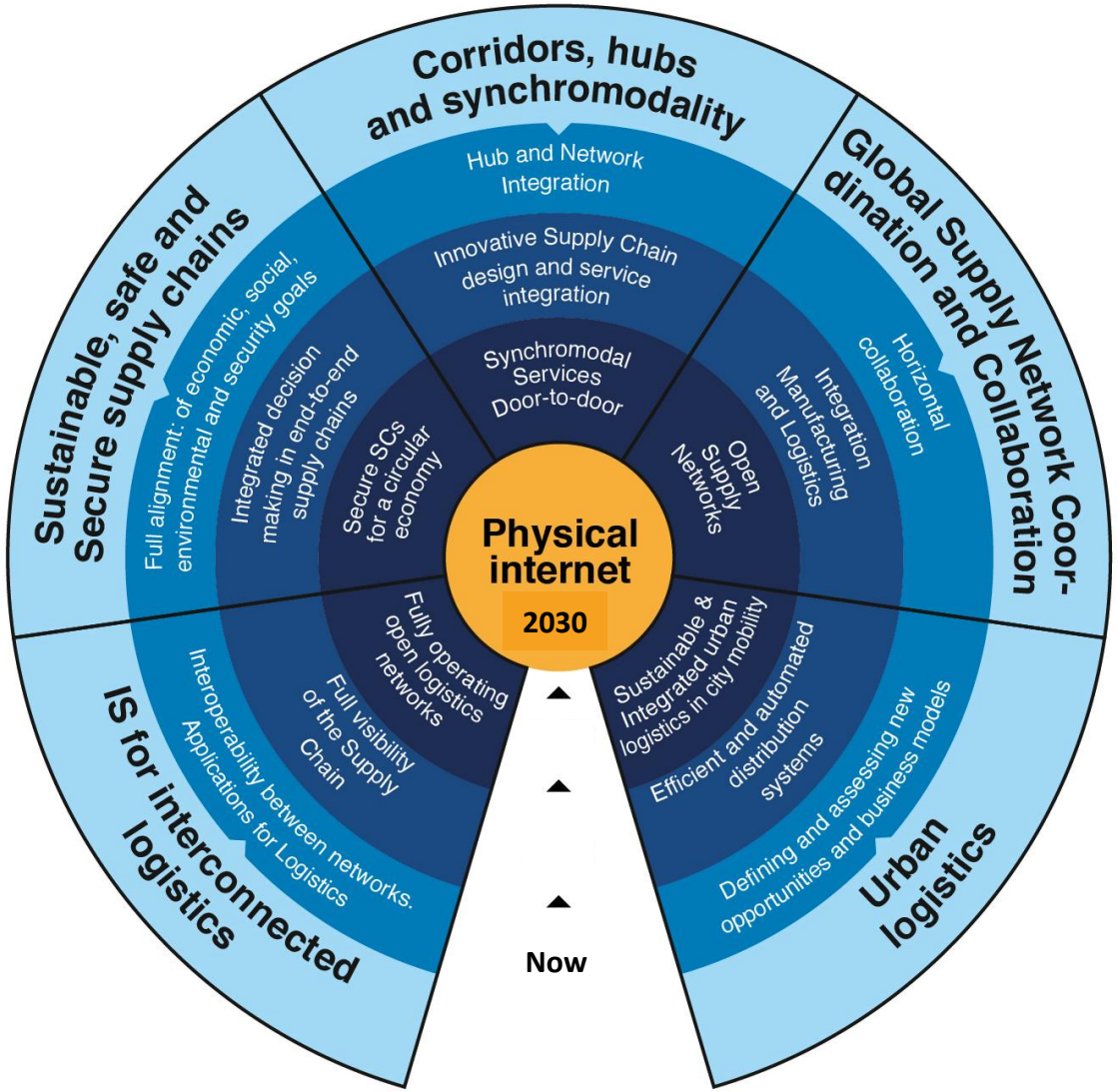
Proximity pre-positioning of products based on smart predictive analytics

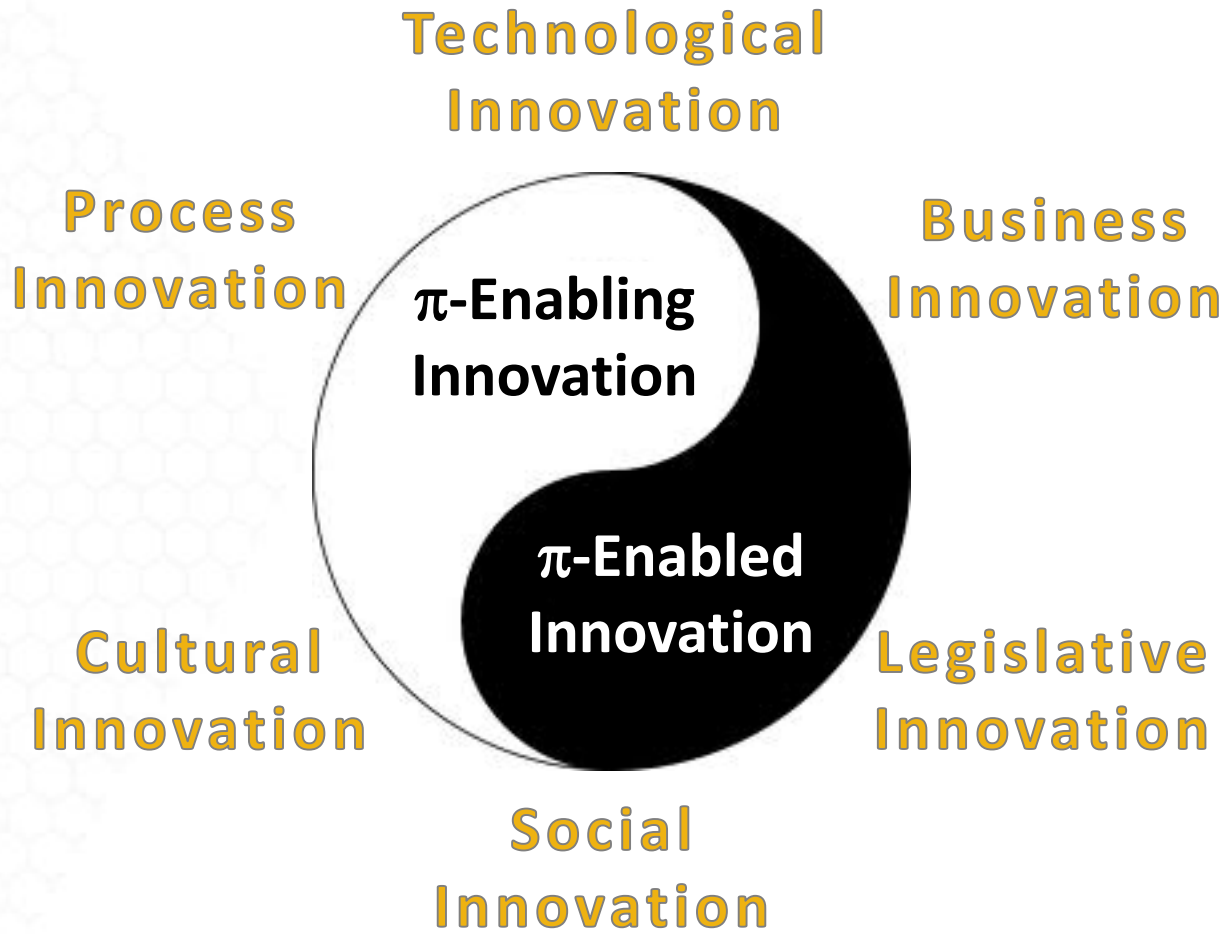


B. Montreuil et al., "Urban Parcel Logistics Hub and Network Design: The Impact of Modularity and Hyperconnectivity", Proceedings of IMHRC 2018, to appear., 2018

Innovation Driven Journey

Grasp Vision, Aim for Early Quick Wins, Act along Roadmap, Adapt to Evolving Landscape





π : Physical Internet

Adapted from www.etp-logistics.eu

Questions, comments, ideas are most welcome

Thanks!

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