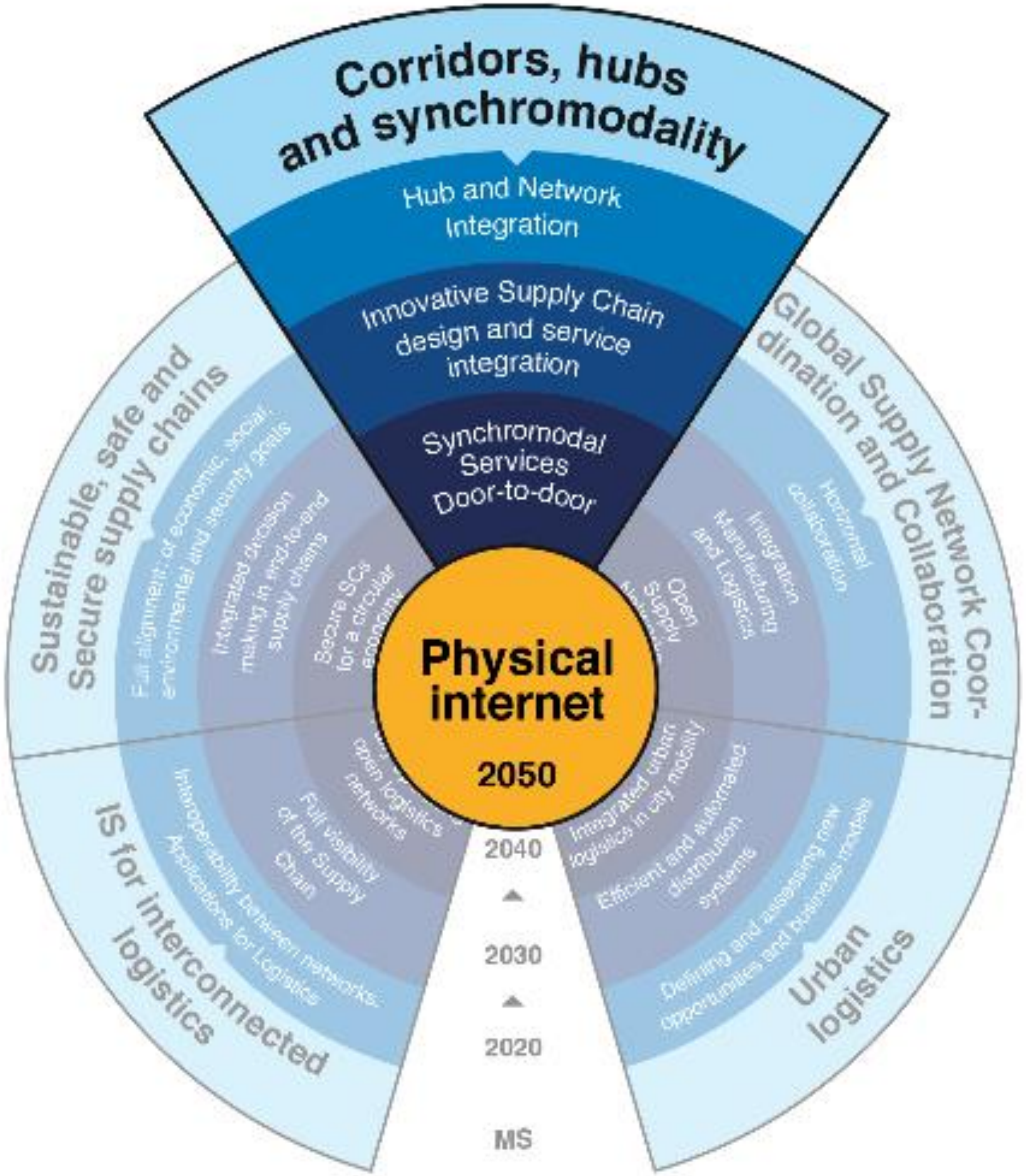
THE FIRST CLASS LOGISTICS HUB

WG2 - KEY MILESTONES

- **2020** – Hub and network integration
- **2030** – Innovative supply chain design and synchromodal service integration
- **2040** – Synchromodal services door to door
- **2050** – Physical Internet



WORKSHOP 10.1 – PI HUBS AND NETWORKS

- OPTIMAL ORDERING AND TRANSPORTING OF INVENTORY IN SMALL PI-NETWORK
  Gerlach Van der Heide (University of Groeningen)
- SIMULATION-BASED ASSESSMENT OF HYPERCONNECTED DISTRIBUTION CENTER CAPACITY REQUIREMENTS AND SERVICE CAPABILITIES
  Nayeon Kim (Georgia University of Technology)
- A SIMULATION-BASED STUDY OF THE EFFECT OF COMPETITION ON THE OPERATIONS OF HYPERCONNECTED CROSSDOCKING HUBS
  Shannon Buckley (Georgia University of Technology)
- TOWARDS HYPERCONNECTED PI-HUBS – LINKING SUPPLY CHAIN OPERATIONS
  Tomasz Dowgielewicz (MARLO Poland)

Optimal ordering and transporting of inventory in small PI-networks

Gerlach van der Heide

I.F.A. Vis, K.J. Roodbergen, P. Buijs

IPIC 2017

Project

- Towards Virtual Ports in a Physical Internet

Introduction

- Physical Internet + Internet of Things
- Track items during transportation
- Up-to-date inventory information
- Dynamic routing of items in transit

Introduction

Situation:

- One company
- A given network of warehouses
- Dynamic routing allowed
- Storage possible at all warehouses

Introduction

Situation:

- One company
- A given network of warehouses
- Dynamic routing allowed
- Storage possible at all warehouses

Research goals:

- Optimize decisions for orders and shipments
- Analyze network flows
- Compare with static routing
- Study impact of missing edges

The network

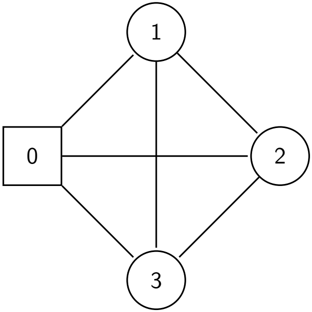


Figure: Part of the PI-network used by the company

- Orders arrive at node 0
- Random demand at nodes 1, 2, and 3
- When and how much to order? How much to ship over each edge?

Model

- Periodic decisions
- Order of events:
  1. Incoming orders and shipments arrive
  2. New order and shipment decisions are taken
  3. Random demand arrives
  4. Inventory costs are incurred

Model

- Periodic decisions
- Order of events:
  1. Incoming orders and shipments arrive
  2. New order and shipment decisions are taken
  3. Random demand arrives
  4. Inventory costs are incurred

- Assumptions:
  - Shipments and orders take one period
  - Always transport available
  - No batching/capacities
  - Time-homogeneous costs and demand distributions

Costs

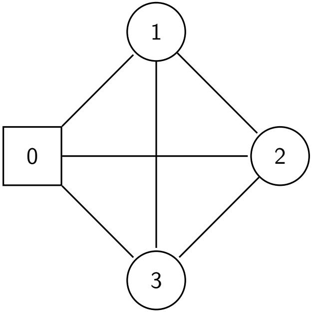
- Identical cost parameters at each node.
- Customer behavior: backorders or lost sales
- Parameters:
  - Holding cost h per unit per period (also for stock in transit)
  - Shipment cost c per unit
  - Order cost K per order
  - Backorder cost b per unit per period
  - Lost sales cost ℓ per unit

Costs

- Identical cost parameters at each node.
- Customer behavior: backorders or lost sales
- Parameters:
  - Holding cost h per unit per period (also for stock in transit)
  - Shipment cost c per unit
  - Order cost K per order
  - Backorder cost b per unit per period
  - Lost sales cost ℓ per unit

- Determine order and shipment decisions with minimal long-run average costs per period
- Solve Markov Decision process

university of groningen



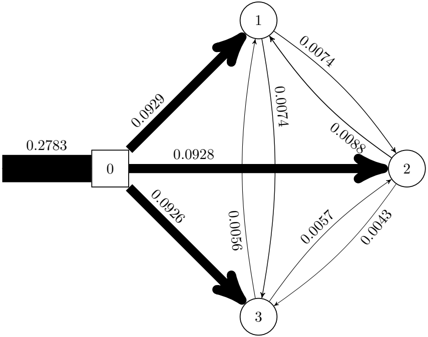
- We vary:
  - Shipment costs: $c = 0$ or $c = 5$
  - Demand variability: low or high
  - Customer behavior: lost sales or backorders
- Other parameters: $h = 1$, $K = 50$, $b = 20$, $\ell = 60$
- Average demand at nodes 1,2, and 3: 0.1

Network flows with dynamic routing

- Situation: lost sales and low demand variability

- Situation: lost sales and low demand variability

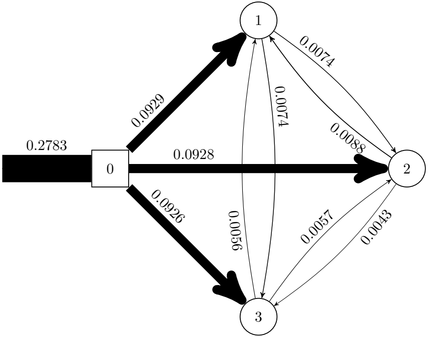
Positive shipment costs ($c = 5$)



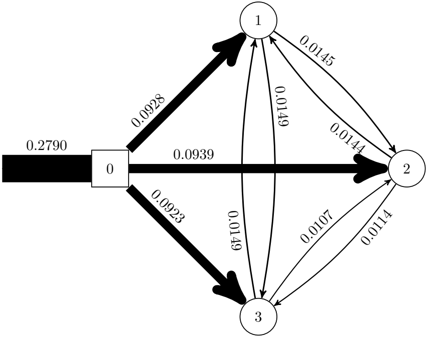
Network flows with dynamic routing

- Situation: lost sales and low demand variability

Positive shipment costs ($c = 5$)



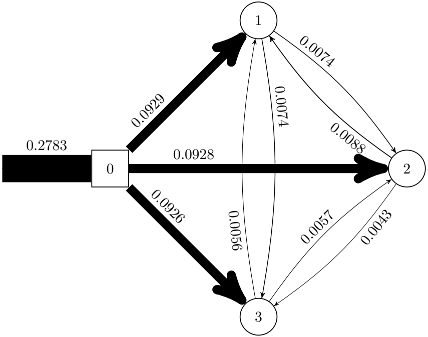
No shipment costs ($c = 0$)



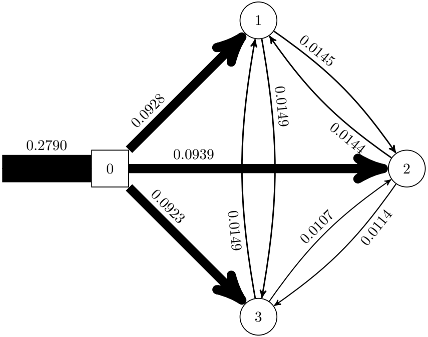
Network flows with dynamic routing

- Situation: lost sales and low demand variability

Positive shipment costs ($c = 5$)



No shipment costs ($c = 0$)



- Total flow for $c = 0$ is 13% higher
- Indirect edges are used 106% more

Static vs dynamic routing

- Static routing: select end-nodes when placing order
- How much better is dynamic routing?

Table: Cost reduction of dynamic routing

Lost sales		
	$c = 0$	$c = 5$
Low variability	14.69%	10.27%
High variability	8.57%	4.71%

Static vs dynamic routing

- Static routing: select end-nodes when placing order
- How much better is dynamic routing?

Table: Cost reduction of dynamic routing

Backorders		
	$c = 0$	$c = 5$
Low variability	17.31%	12.47%
High variability	15.91%	10.06%

Static vs dynamic routing

- Static routing: select end-nodes when placing order
- How much better is dynamic routing?

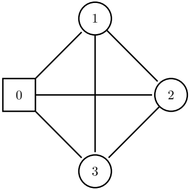
Table: Cost reduction of dynamic routing

Backorders		
	$c = 0$	$c = 5$
Low variability	17.31%	12.47%
High variability	15.91%	10.06%

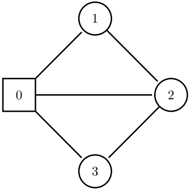
- Significant cost savings from dynamic routing!
- Remark: dynamic routing has larger flows

Costs of missing edges

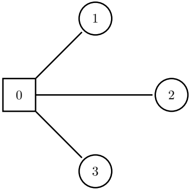
- What is the cost of missing edges?
- Compare with other graphs:



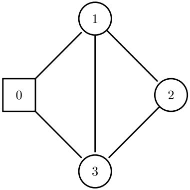
Complete graph



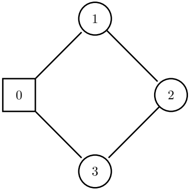
A1



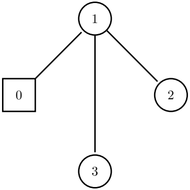
A2



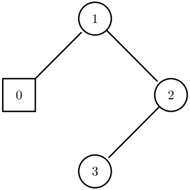
B1



B2

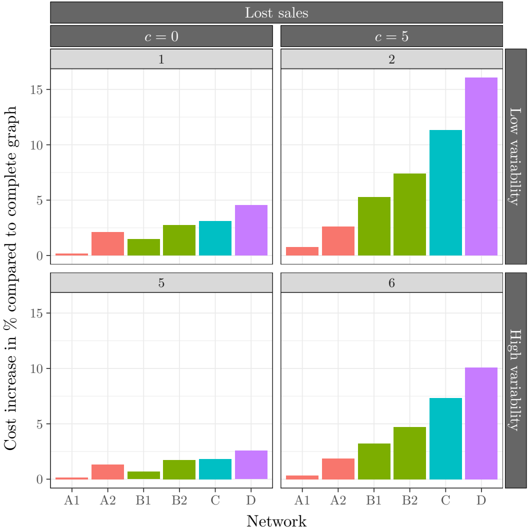


C

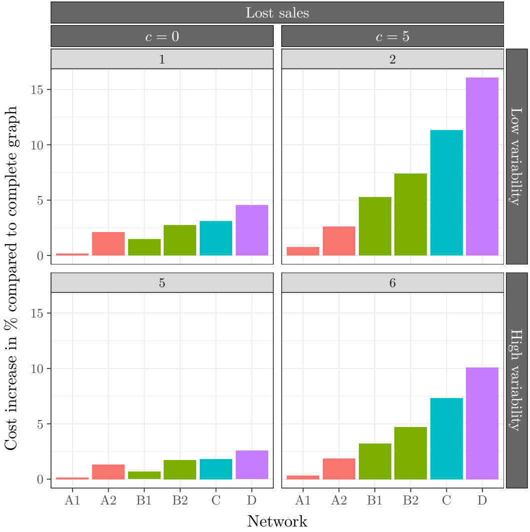


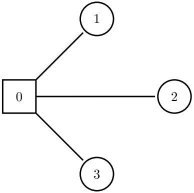
D

Network comparisons

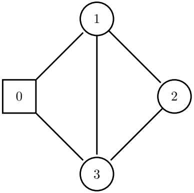


Network comparisons



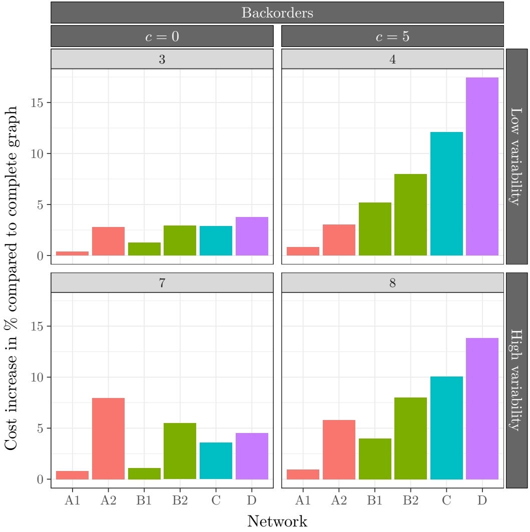


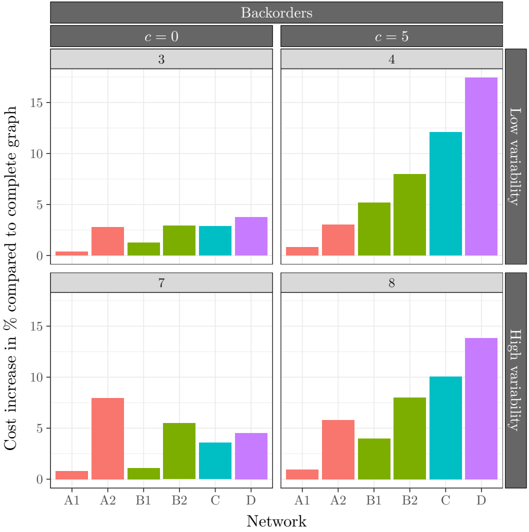
A2



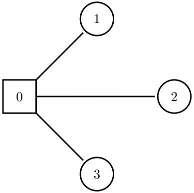
B1

Network comparisons



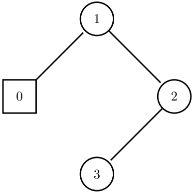


Backorders
c = 0
c = 5
3
4
7
8
Low variability
High variability
Cost increase in % compared to complete graph
0
5
10
15
A1
A2
B1
B2
C
D
Network



0
1
2
3

A2



0
1
2
3

D

Network comparisons

- Mostly distance first, then flexibility (more edges)
- With backorders:
  - Consideribly different ranking with low shipment costs and high demand variability
  - Flexibility much more important than distance
  - Two-echelon-like network can be worst of all!

Conclusions

- Dynamic routing leads to significant costs savings over static routing
- Low shipment costs increase usage of indirect edges
- Customer behavior has substantial impact on effectiveness of networks with missing edges
- Optimal behavior must be accounted for in network design, pricing mechanisms, etc.

Simulation-based Assessment of Hyperconnected Mixing Center Capacity Requirements and Service Capabilities

4th International Physical Internet Conference
6/Jul/2017

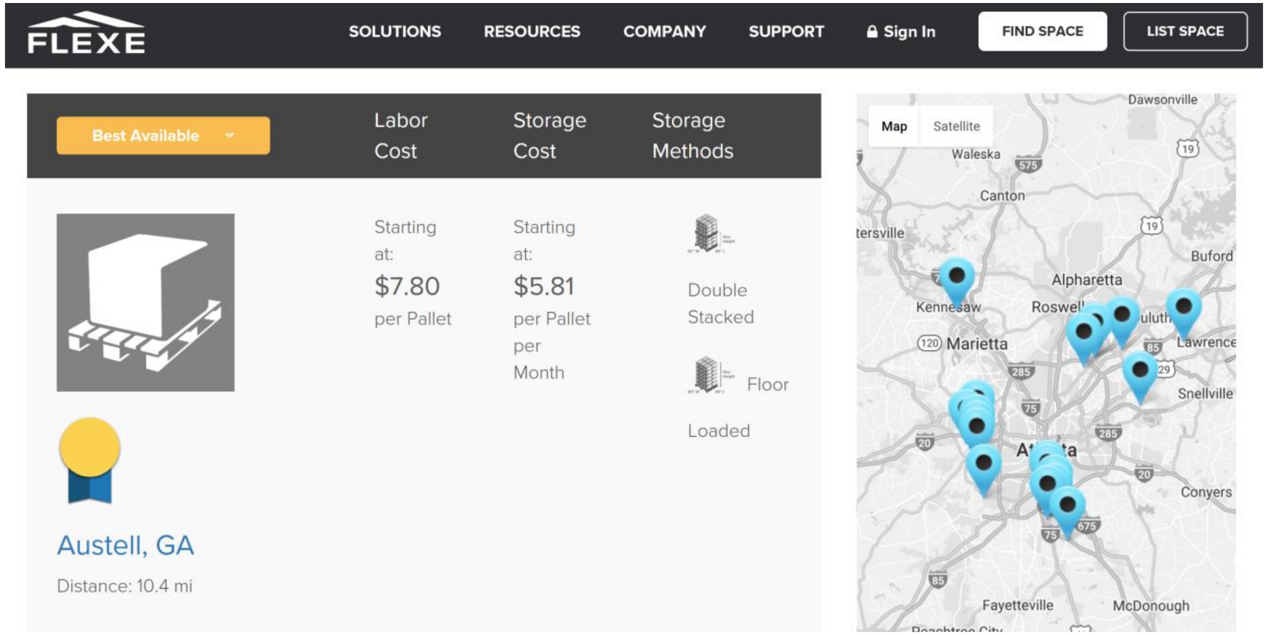
Nayeon Kim [1,2] & **Benoit Montreuil** [1,2,3,4]

1. H. Milton Stewart School of Industrial & Systems Engineering, Georgia Institute of Technology
2. Physical Internet Center
3. Supply Chain & Logistics Institute
4. Coca-Cola Chair in Material Handling and Distribution

Corresponding author: nkim97@gatech.edu

Openly Shared Distribution

- ES3 in York, PA
- Fulfillment by Amazon
  - 100+ fulfillment centers in North America
- Flexe.com
  - Hyperconnected on-demand warehousing platform



Hyperconnected Mixing Center (HMC)

- Definition of mixing center by comparison to warehouses and distribution centers:

	Warehouse	Mixing Center	Distribution Center
Storage Type	Deep extended storage	Short term flow storage	Short term flow storage
User Type	Manufacturers, Retailers	Manufacturers	Retailers, Distributors

- Comparison of three types of mixing centers (MCs)

	Dedicated MC	Collaborative MC	Hyperconnected MC
Users	Single Manufacturer	Exclusive group of partnered manufacturers	Open on demand to any manufacturer

- Extreme variants of hyperconnected mixing center (HMC)
    - Spot HMC and Steady HMC

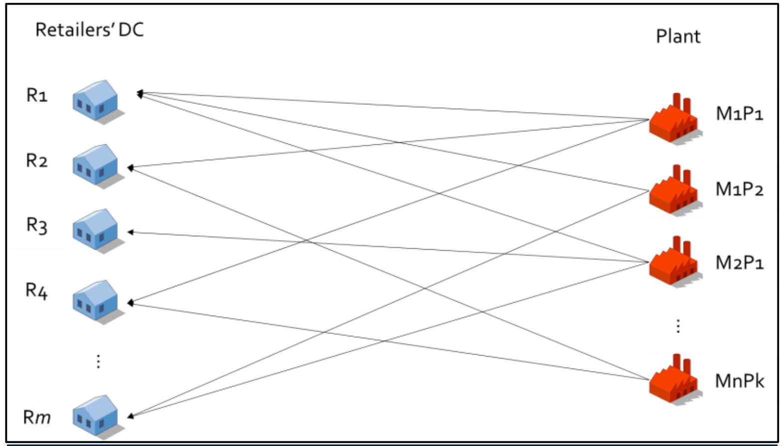
Key Players

- Key Players:
  - Manufacturers
  - Retailers
  - Carriers
  - Logistics service provider(LSP)

- Hyperconnected MC can be operated by manufacturer(s) or LSP

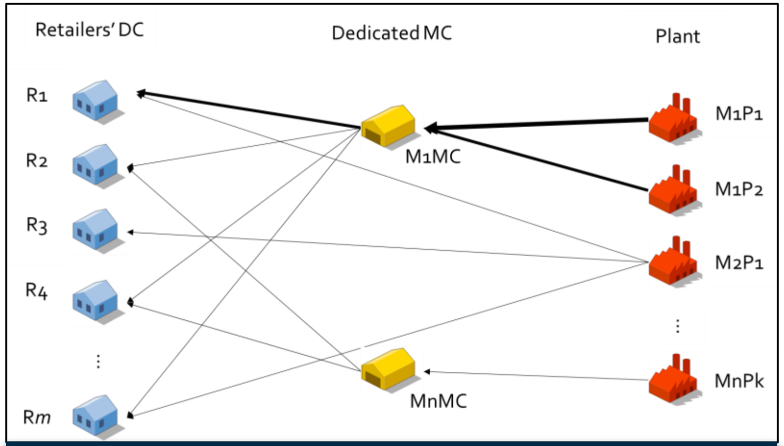
Alternative Operation Scenarios and KPIs

- Alternative operation scenarios



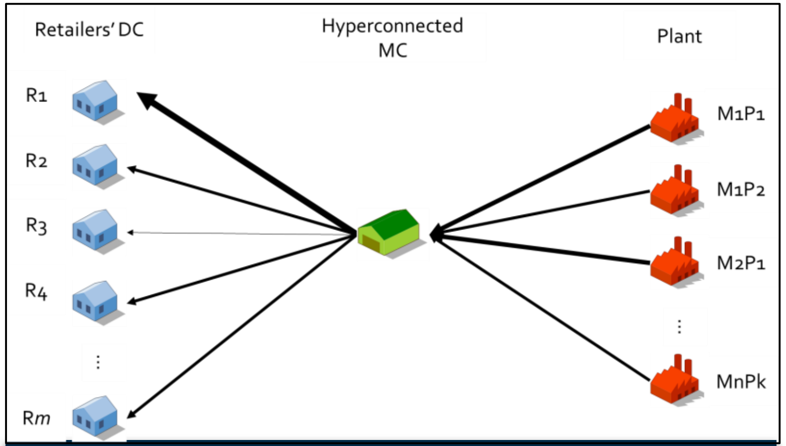
No MC (Plant Warehouses)

- No capital investment
- Long lead time
- Low consolidation



Dedicated MC

- Large capital investment
- Short lead time
- Better consolidation



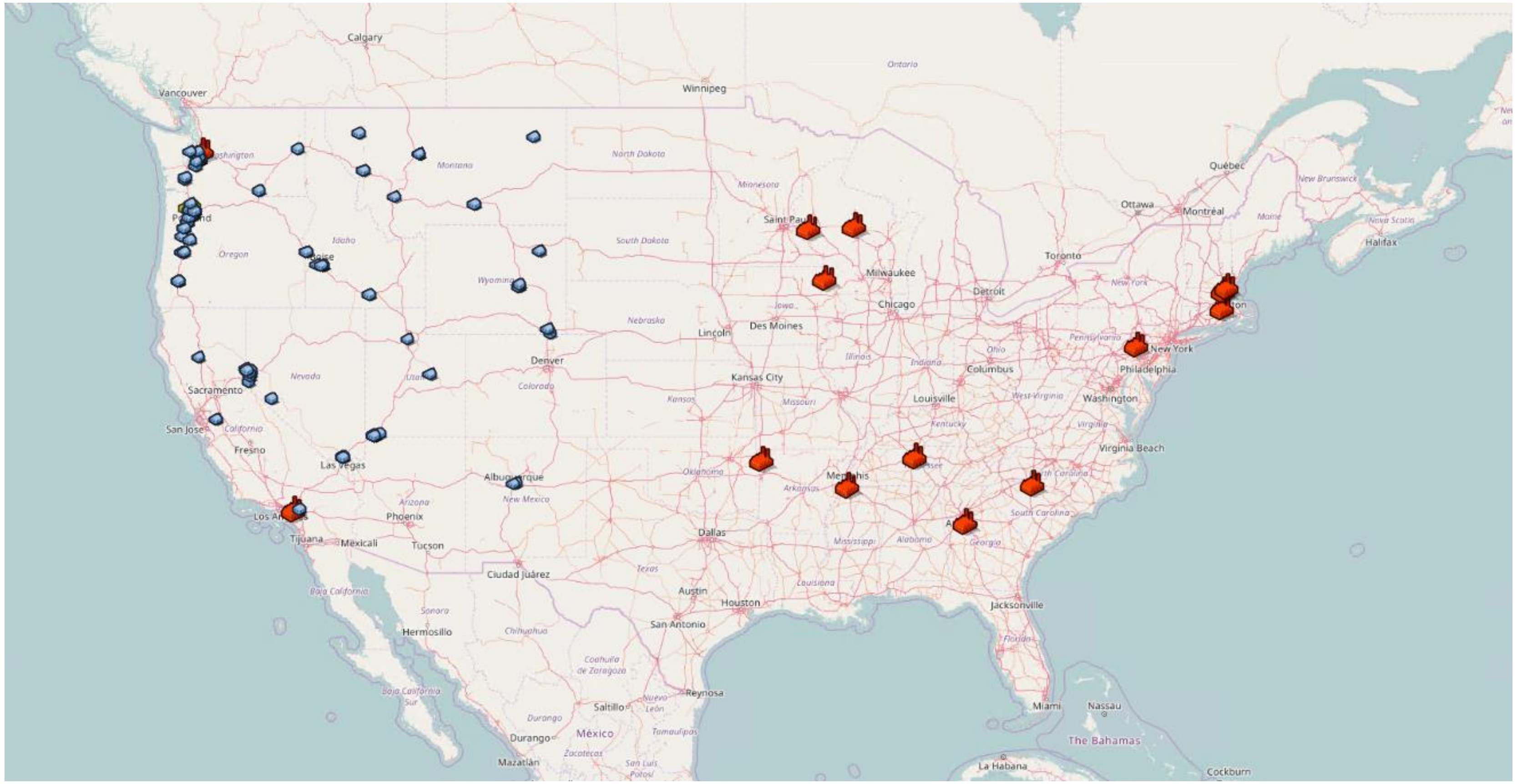
Hyperconnected MC

- Low/no capital investment
- Short lead time
  - Travel miles reduction
- High consolidation

- Key performance indices (KPIs)
  - E.g. Induced travel miles, inventory requirements (average, variability, peak), service level (delivery frequency)

Case Description

- Implementing a new steady hyperconnected MC serving U.S. western states operated by a logistics service provider
- Potential clients of the HMC are consumer goods manufacturers



Operation and Experimental Scenarios

- Operation Scenarios:
  - No MC, Dedicated MC, and Hyperconnected MC
- Experimental Scenarios:

Scenario ID	# of Clients at MC (# Manufacturers)	Average Annual Throughput (M pallets/year)	# of distinct outbound destinations (Customer DCs)
1	2	~2.8	139
2	5	~2.8	173
3	8	~2.8	180
4	12	~5.8	194
5	8	~3.4	195
6	13	~1.0	172

Capacity Requirements

- Hyperconnected MC can reduce required storage capacity of manufacturers compared to No MC or Dedicated MC operation mode
  - Compare capacity requirements of dedicated facilities to responsible capacity in HMC
- The size of reduction can differ by client configuration of HMC

Scenario ID	Annual Throughput /# Clients (M pallets)	Capacity Requirement (K Pallets)	Average Capacity Requirement Reduction		0.99 percentile of OHI (K Pallets)
			From No MC to Hyperconnected	From Dedicated to Hyperconnected	
1	~2.8 / 2	200	0%	2%	185
2	~2.8 / 5	232	0%	0%	217
3	~2.8 / 8	241	5%	6%	222
4	~5.8 / 12	440	6%	7%	408
5	~3.4 / 8	281	13%	14%	259
6	~1.0 / 13	103	16%	16%	94

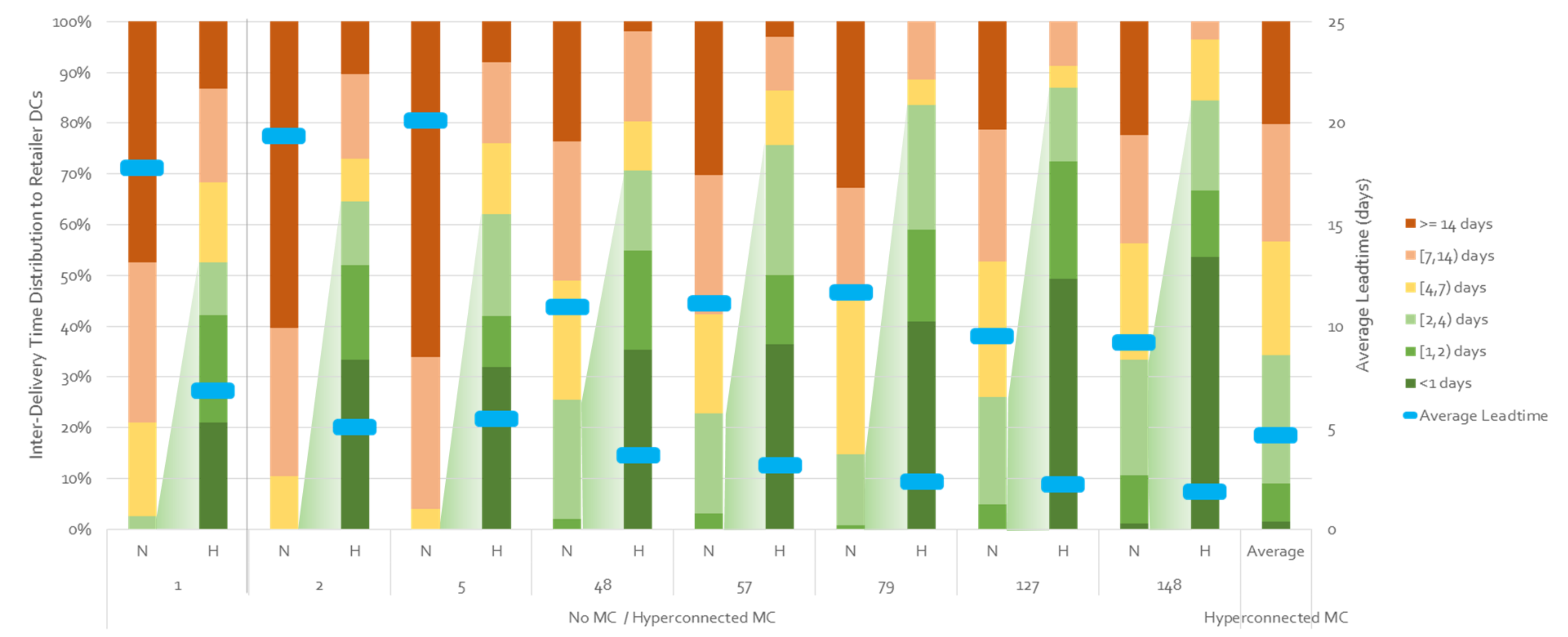
Average Inter-delivery Time

- HMC can significantly reduce average inter-delivery time to retail DCs by consolidating multi-retailer shipments to same destination without increasing outbound travel distances

Scenario ID	Consolidation Index	Average Inter-Delivery Time in Days and Marginal Reduction					Average Marginal Reduction in Outbound Travel Distances		
		No MC	Dedicated MC		Hyper MC		No MC	From No MC to Dedicated MC	From Dedicated MC to Hyper MC
1	1.4	8.8	2.6	71%	2.1	18%	-	67%	1%
2	1.8	6.4	6.4	0%	3.4	46%	-	0%	59%
3	2.6	13.7	11.4	17%	4.7	59%	-	27%	40%
4	3.8	11.1	9.1	18%	2.3	75%	-	24%	39%
5	3.1	12.6	11.4	9%	4.3	62%	-	18%	51%
6	2.2	16.1	14.9	7%	9.7	35%	-	19%	55%

Average Inter-delivery Time

- Large manufacturers can also improve their service level



Average Inter-delivery Time to Retailer DC in No MC Operation (N) and in Hyperconnected MC Operation (H) in Scenario 3

Inventory Operation at Customer(Retail) DCs

- Inventory operation at customer DCs can be improved by increased delivery frequency with HMC
- Capacity requirements and inventory variation are reduced

Scenario ID	Reduction in 0.99 Percentile OHI at Customer DC		Reduction in Inventory Variation (COV*) at Customer DC	
	No MC to Hyper MC	Dedicated MC to Hyper MC	No MC to Hyper MC	Dedicated MC To Hyper MC
1	16%	0%	62%	27%
2	15%	15%	46%	46%
3	10%	3%	69%	59%
4	10%	5%	76%	71%
5	9%	6%	70%	68%
6	6%	3%	52%	49%

**COV: Coefficient of Variation (Standard Deviation / Mean)*

Summary

- Simulation-based methodology to understand and assess the impact of hyperconnected storage and distribution through a hyperconnected MC is proposed

- Potential advantages of a steady HMC are shown
  - Storage capacity requirements can be reduced
  - Delivery frequency can be increased, even for large manufacturers
  - Outbound travel miles can be reduced
  - Inventory operation at customer DCs can be improved

- Potential disadvantages of a steady HMC are shown
  - Loss of autonomy and self-control
  - Issue with fair multi-client coordination, prioritization, and pricing
  - Margins shared with logistics service provider

Limitations and Future Research

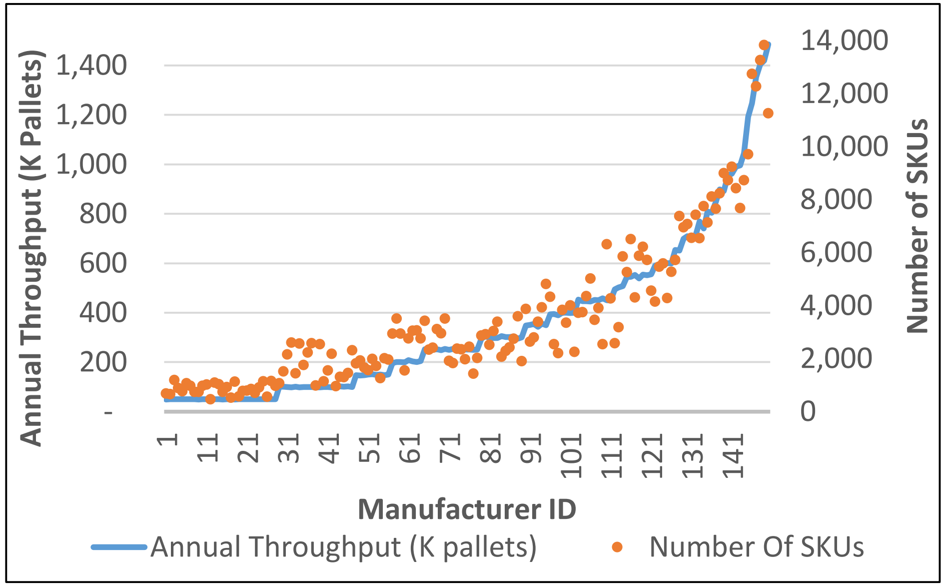
- To be addressed:
  - Coordination cost to handle the complexity and dynamics of HMC
  - Pricing mechanisms for HMC services
  - Long term, multi-year evolution of the clientele of HMCs
  - Multi-HMCs case
  - Competition between HMCs
  - Operation of spot HMCs
  - Integration of HMC and HDC

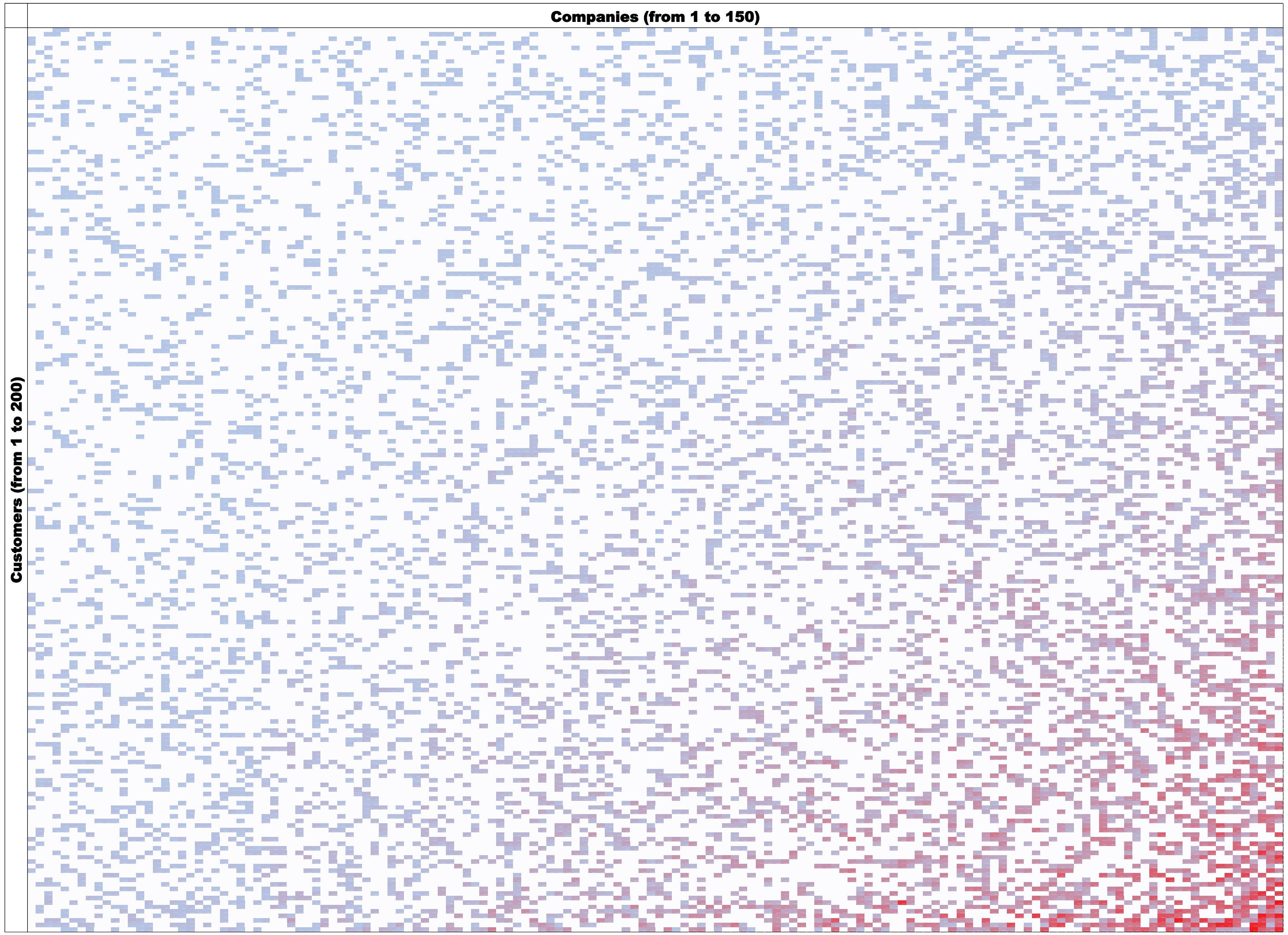
Thank you

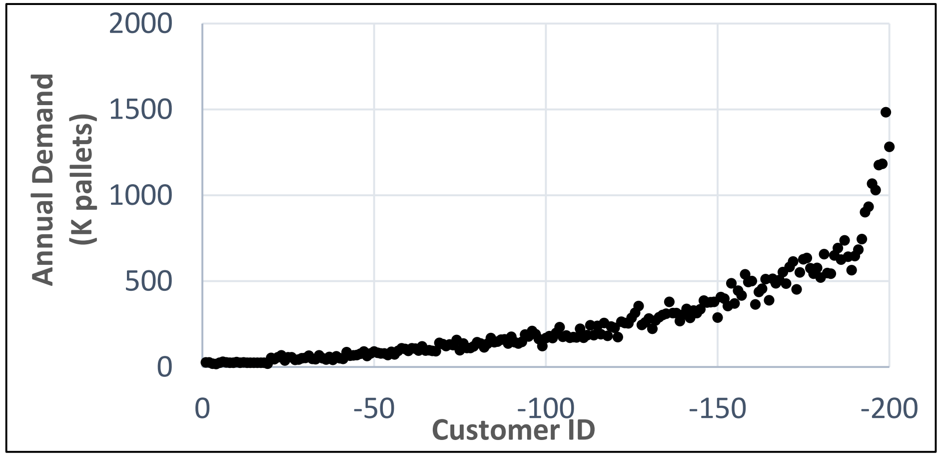
Q&A

Appendix: Key Players-Manufacturers and Retailers

- 150 manufacturers and 200 retailer DCs in the scope







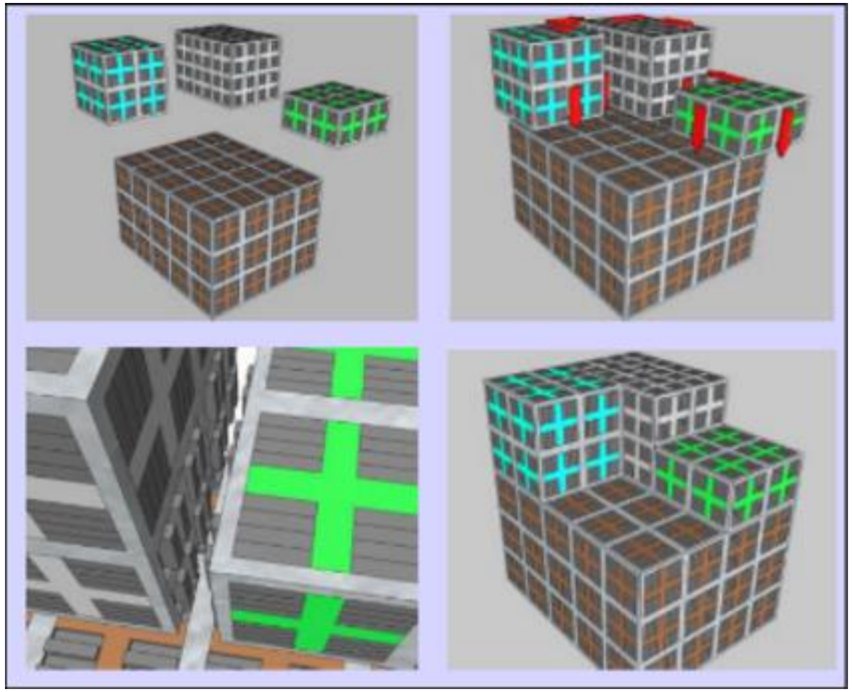
The Effect of Competition on the Operations of Hyperconnected Crossdocking Hubs

By Shannon Buckley, Benoit Montreuil, Zachary Montreuil

Outline

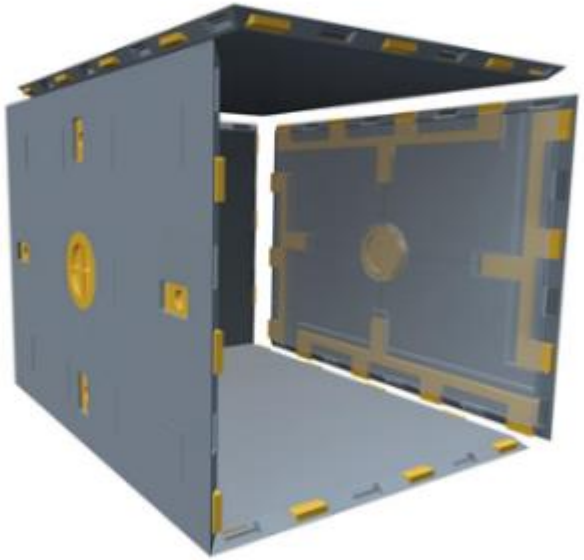
- Background Information
- Our Objective
- The Main Players
- Peri-Urban Hyperconnected Hub Topologies
- Simulation Design
- Results
- Further Avenues for Research

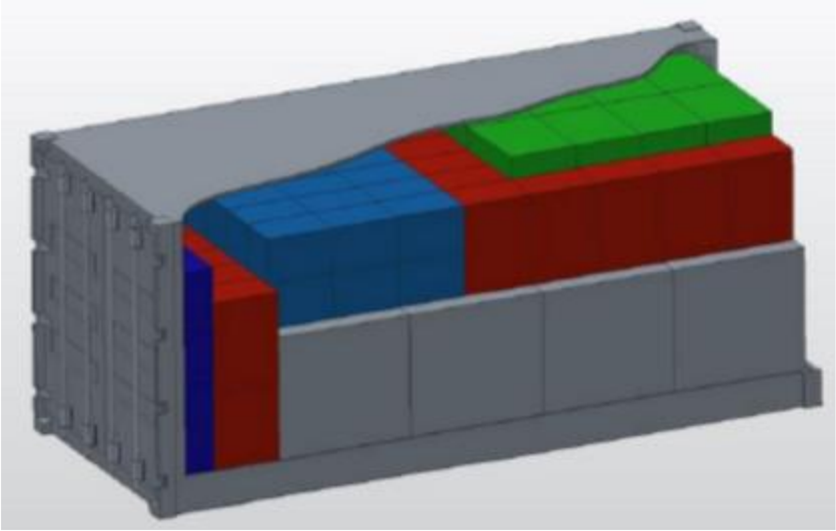
Modular Containers



Montreuil, B., Ballot, E., Tremblay, W. (2015). Modular Design of Physical Internet Transport, Handling and Packaging Containers, Progress in Material Handling Research, v13, MHI, Charlotte, USA.

Modular Containers

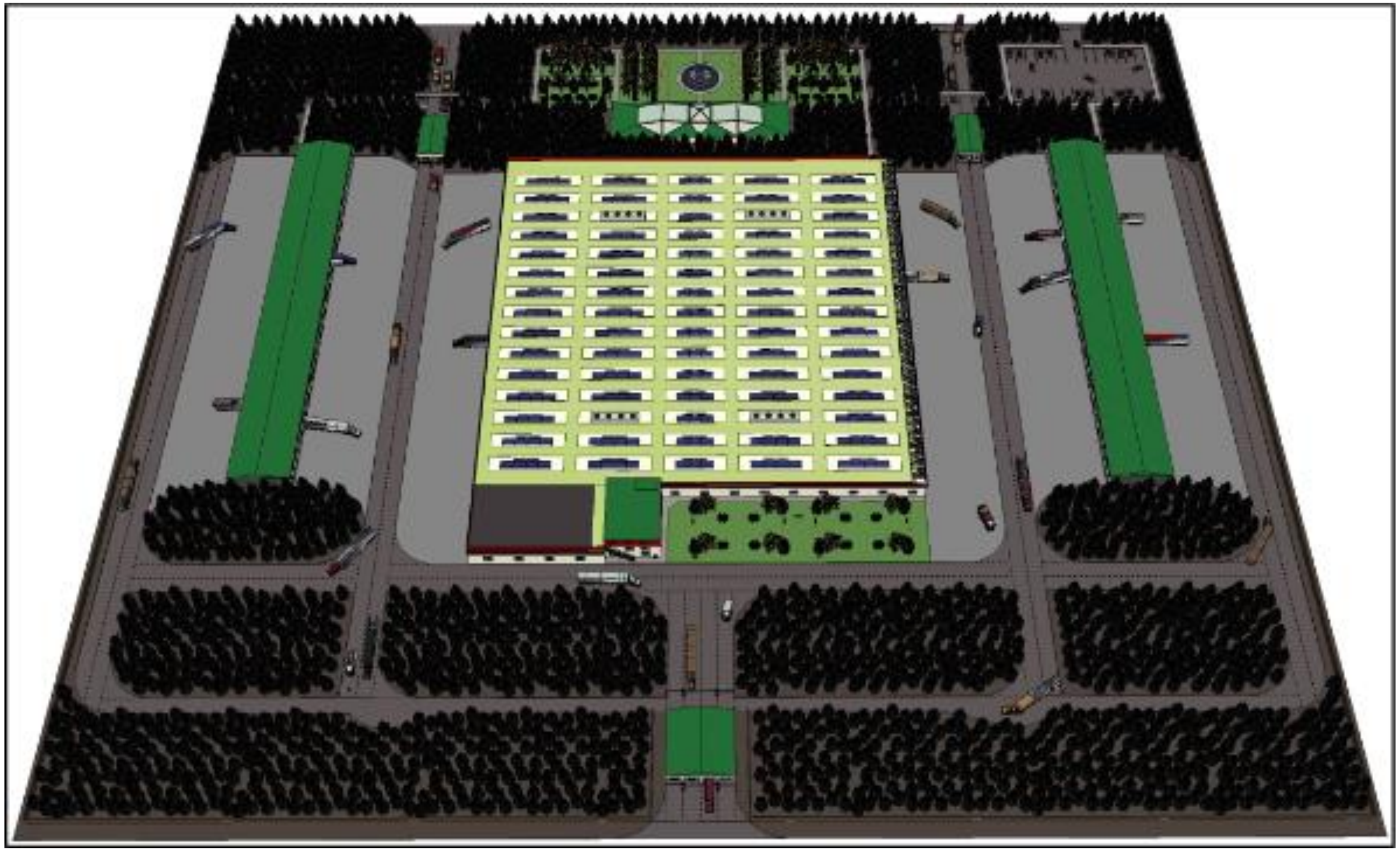




Montreuil, B., Ballot, E., Tremblay, W. (2015). Modular Design of Physical Internet Transport, Handling and Packaging Containers, Progress in Material Handling Research, v13, MHI, Charlotte, USA.

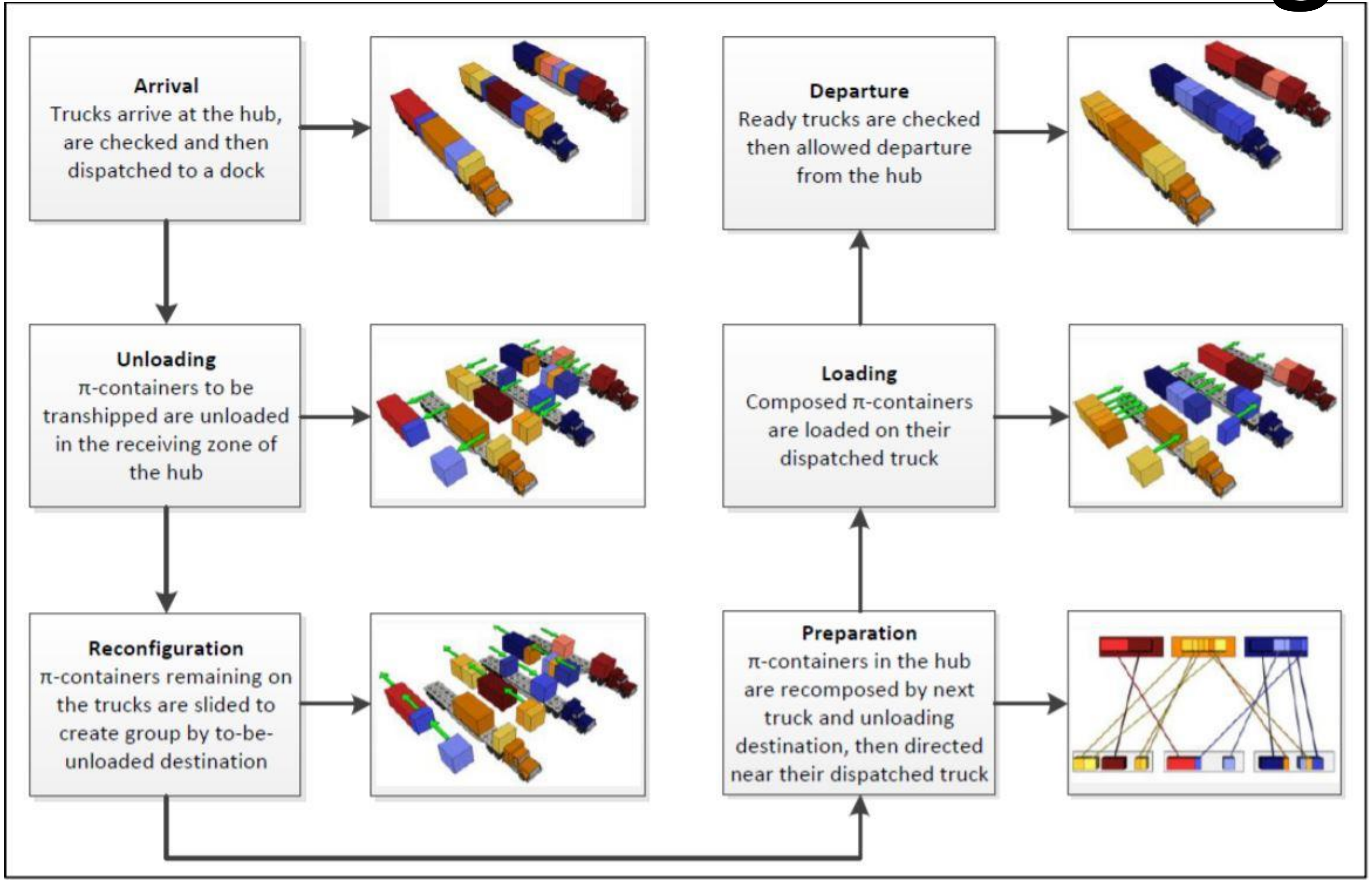
Georgia Tech | Supply Chain & Logistics Institute
Stewart School of Industrial & Systems Engineering

Hyperconnected Crossdocking Hub



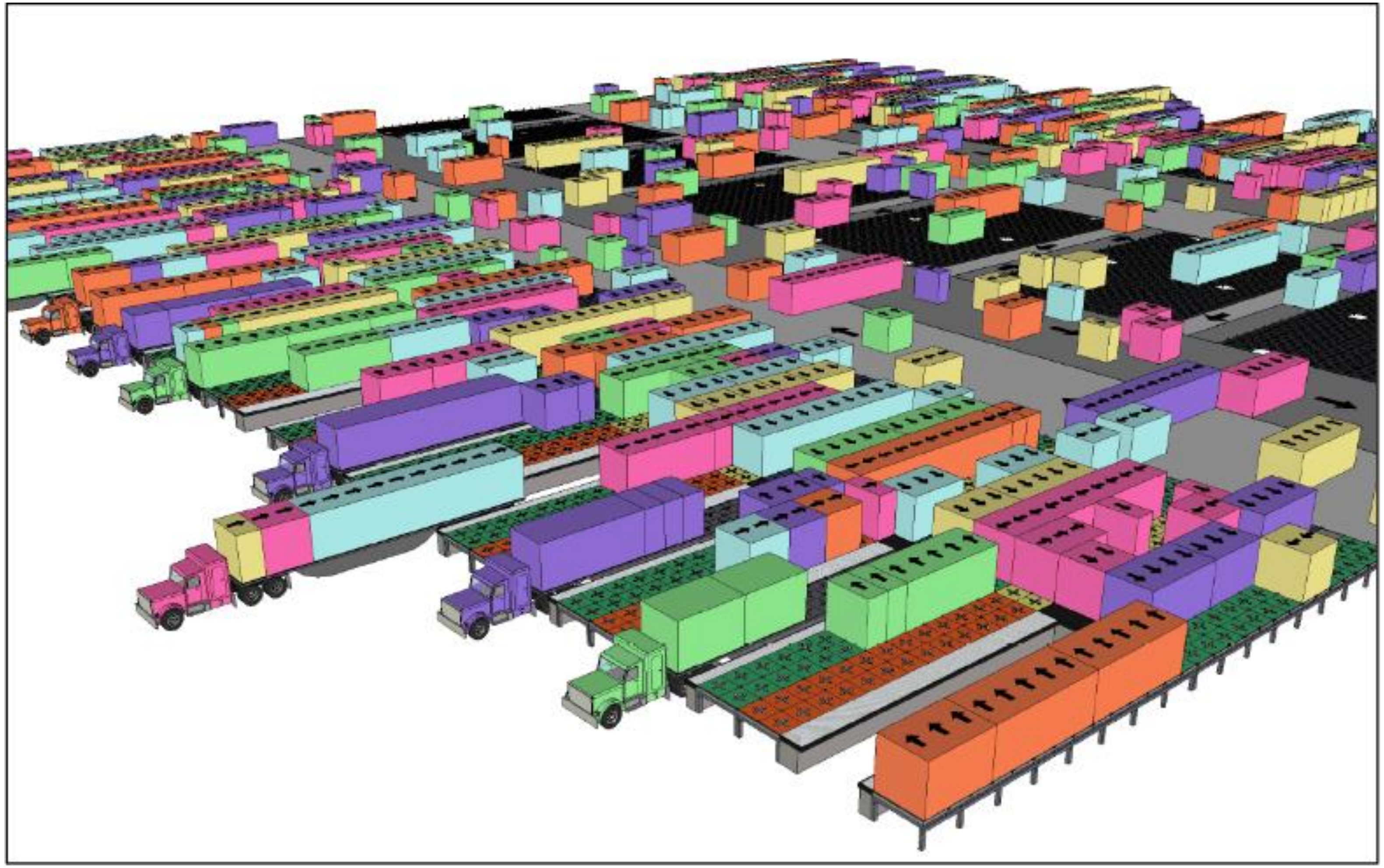
Ballot, E., Montreuil, B., Thivierge, C., and Montreuil, Z., "Functional Design of Physical Internet Facilities:A Road-Based Crossdocking hub," Progress in Material Handling Research: 2012, Material HandlingInstitute, Charlotte, NC, USA (2012).

Hyperconnected Crossdocking Hub



Ballot, E., Montreuil, B., Thivierge, C., and Montreuil, Z., “Functional Design of Physical Internet Facilities:A Road-Based Crossdocking hub,” Progress in Material Handling Research: 2012, Material HandlingInstitute, Charlotte, NC, USA (2012).

Hyperconnected Crossdocking Hub



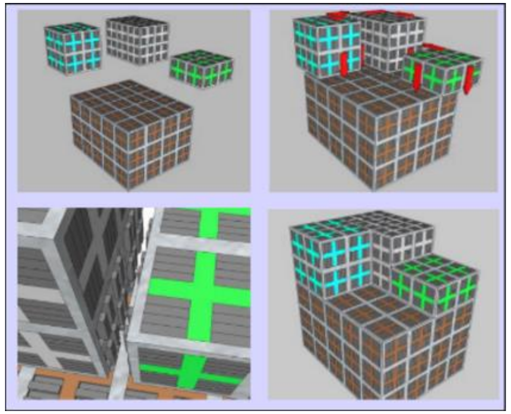
Ballot, E., Montreuil, B., Thivierge, C., and Montreuil, Z., “Functional Design of Physical Internet Facilities:A Road-Based Crossdocking hub,” Progress in Material Handling Research: 2012, Material HandlingInstitute, Charlotte, NC, USA (2012).

Our Objective

- Examine the ways in which multiple hubs within the same region will interact with each other and the other main players in the Physical Internet

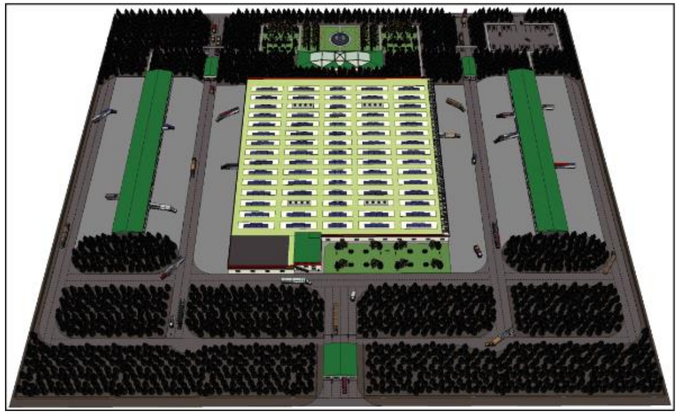
Main Players

Shippers



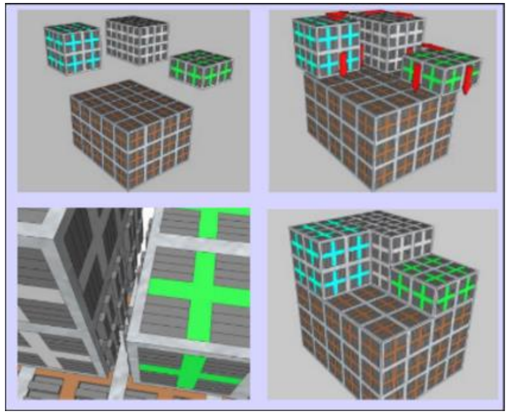
Truckers

Hub Operators



Shippers

- **Large source of demand for PI Hubs**
- **Send PI containers**
- **Objectives:**
  - Make sure shipment is delivered
  - Make sure shipment is delivered on time

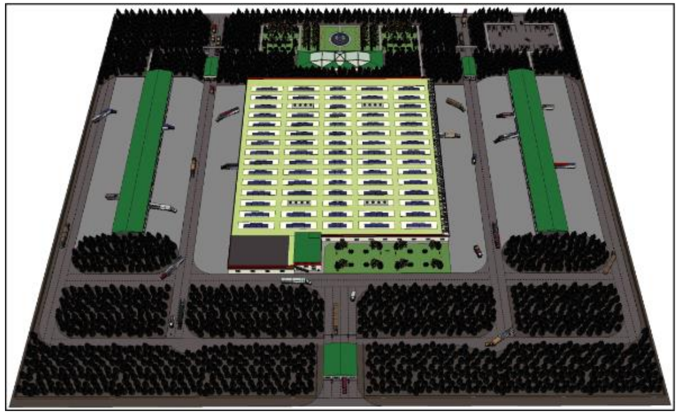


Truckers

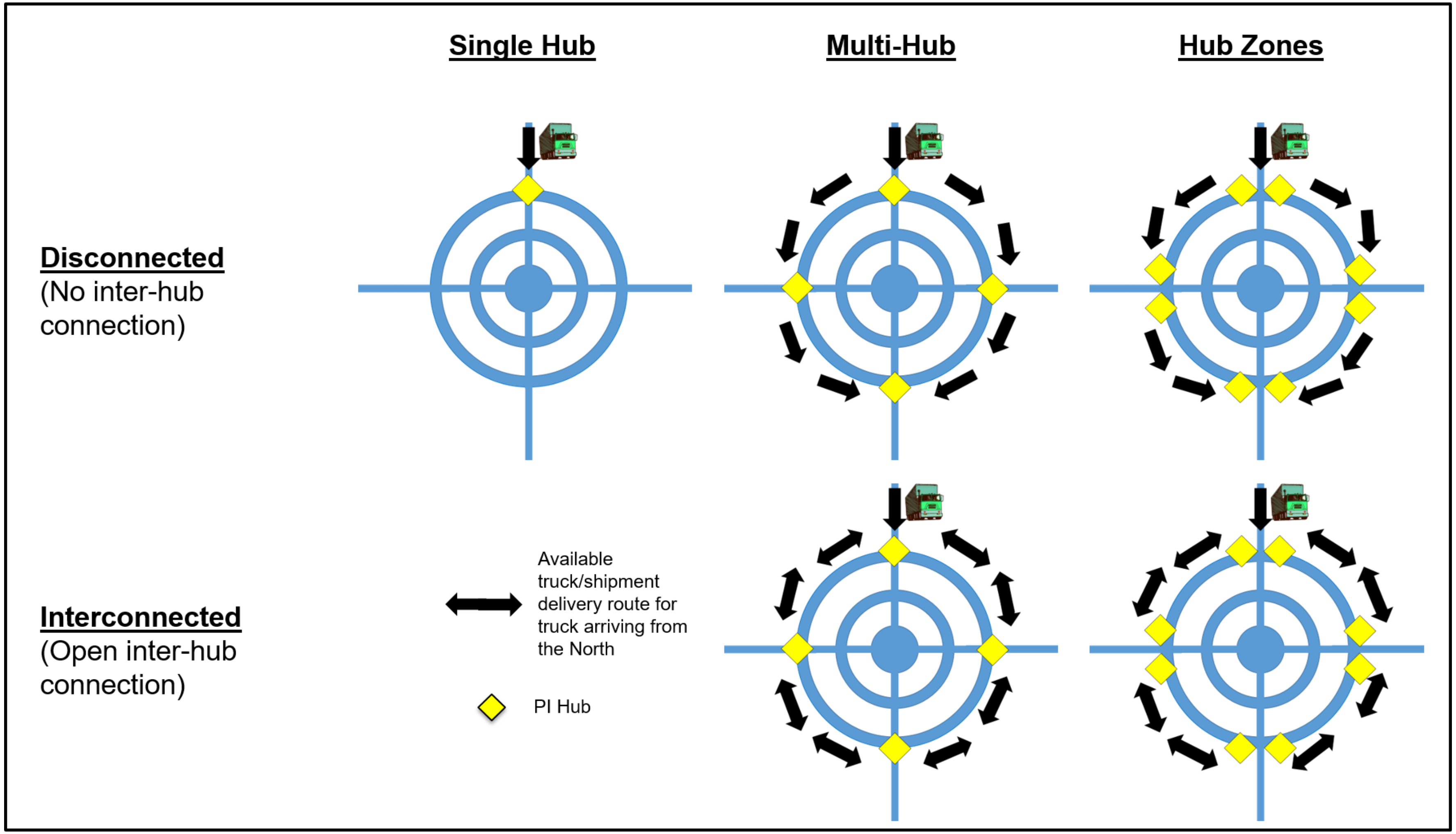
- **The transport providers**
- **Operate independently**
- **PI certified**
- **Objectives:**
  - Make money
  - Maintain quality of life

Hub Operators

- **Control the flow of goods through PI Hubs**
- **PI certified**
- **Manage hub like managing a business**
- **Objective:**
  - Make money



Peri-Urban Hub Topologies



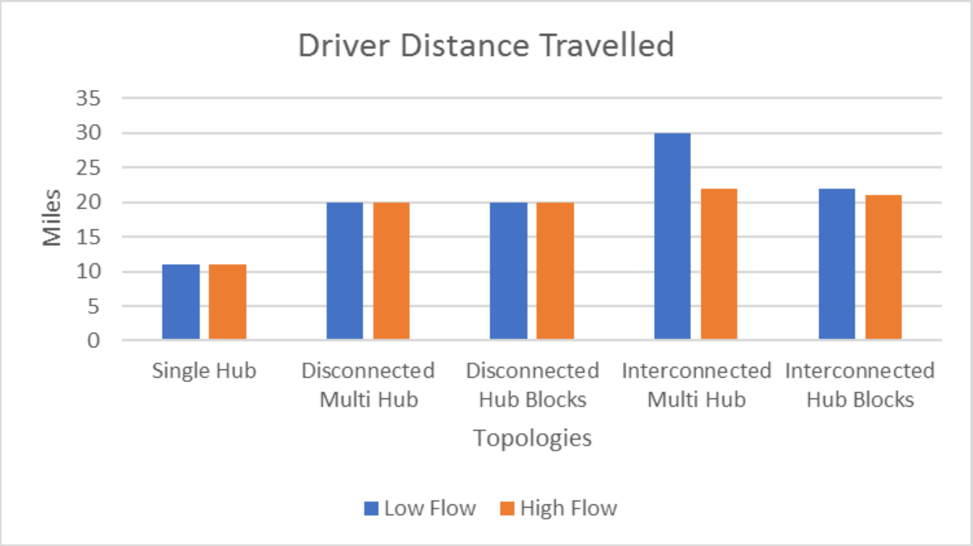
Conclusion

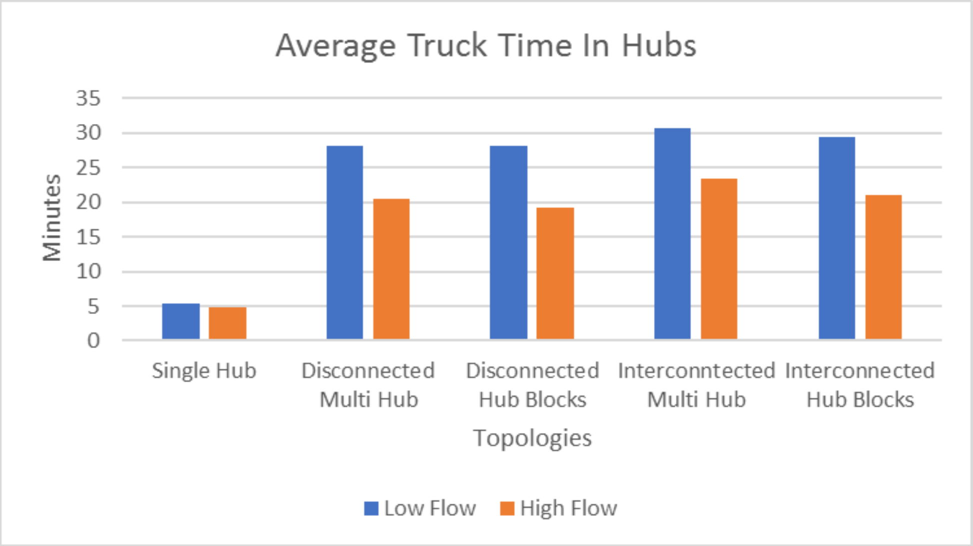
- **Key Learnings:**
  - In “low-flow” scenario, operate under single-hub topology
  - In “high-flow” scenario, single-hub topology had shorter truck and shipment waiting times
  - In “high-flow” scenario, interconnected hubs made for longer waiting times
- **Key Limitations:**
  - No hub capacity limits
  - No shipment expedition if waiting time was too long

Future Research Avenues

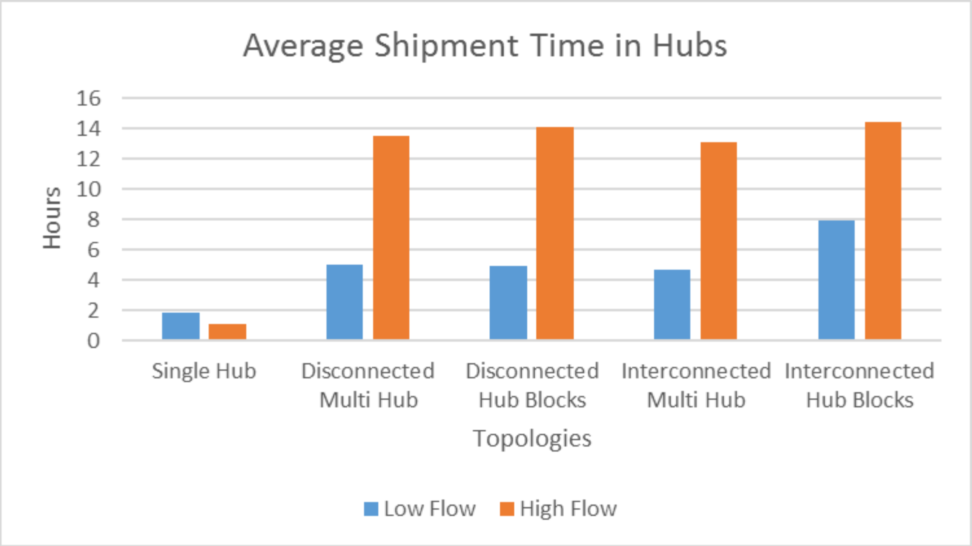
- Add capacity limits to hubs
- Analyze the effect of pricing on shipper's decisions
- Examine scenario with collaborative hubs

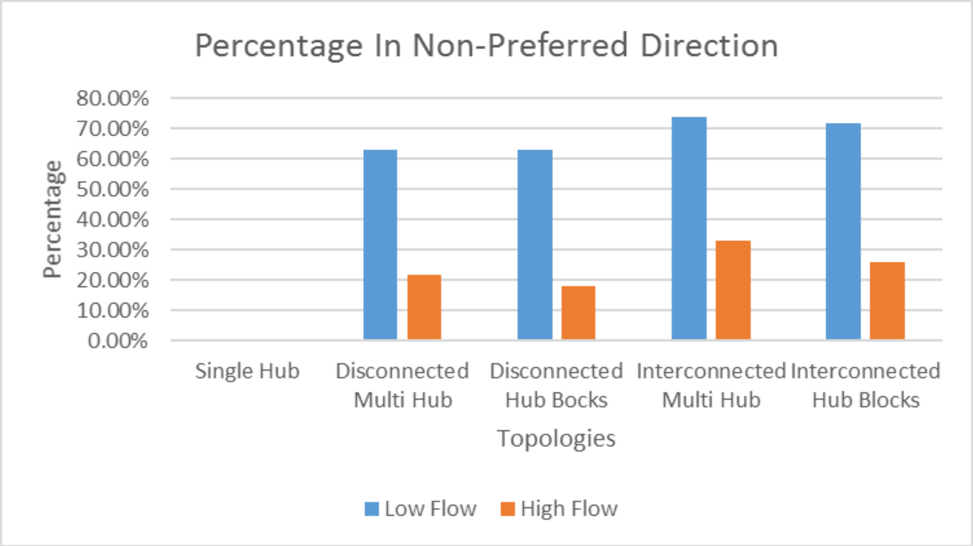
Results


Driver Distance Travelled
Miles
35
30
25
20
15
10
5
0
Single Hub
Disconnected Multi Hub
Disconnected Hub Blocks
Interconnected Multi Hub
Interconnected Hub Blocks
Topologies
Low Flow
High Flow


Average Truck Time In Hubs
Minutes
35
30
25
20
15
10
5
0
Single Hub
Disconnected Multi Hub
Disconnected Hub Blocks
Interconntected Multi Hub
Interconnected Hub Blocks
Topologies
Low Flow
High Flow

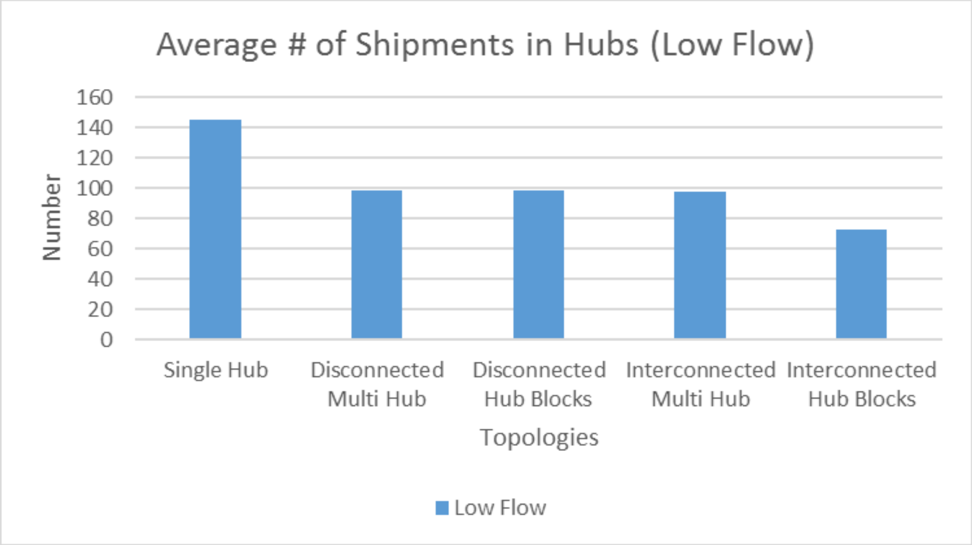
Results



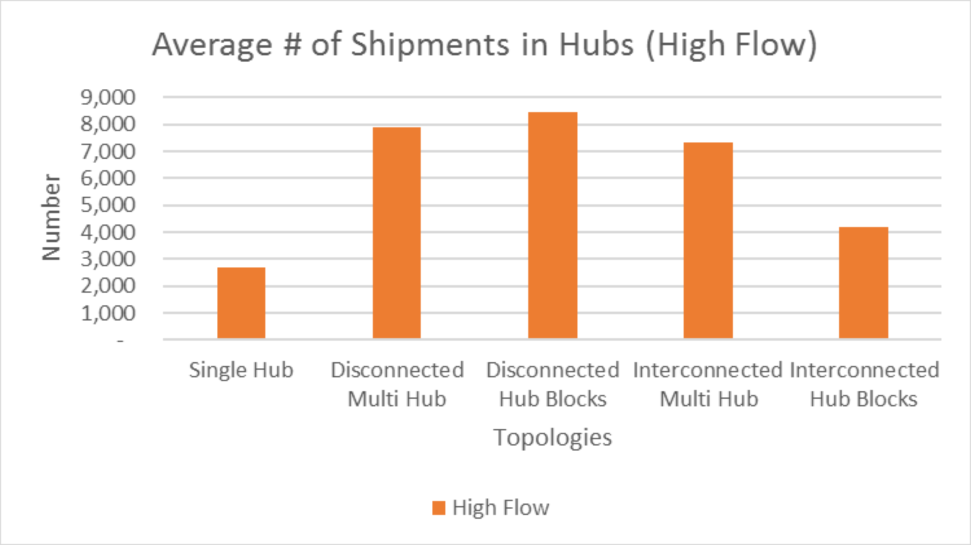


Georgia Tech Supply Chain & Logistics Institute
Stewart School of Industrial & Systems Engineering

Results



Average # of Shipments in Hubs (Low Flow)
160
140
120
100
80
60
40
20
0
Number
Single Hub
Disconnected Multi Hub
Disconnected Hub Blocks
Interconnected Multi Hub
Interconnected Hub Blocks
Topologies
Low Flow



Average # of Shipments in Hubs (High Flow)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
Number
Single Hub
Disconnected Multi Hub
Disconnected Hub Blocks
Interconnected Multi Hub
Interconnected Hub Blocks
Topologies
High Flow

From business need to hyperconnectivity

MIX MOVE
MATCH
Transform your Supply Chain

iCargo project

•Delivery

- Customer Deliveries need to be created at original shipping location (because the Supply Chain lacks the information to do this later on).

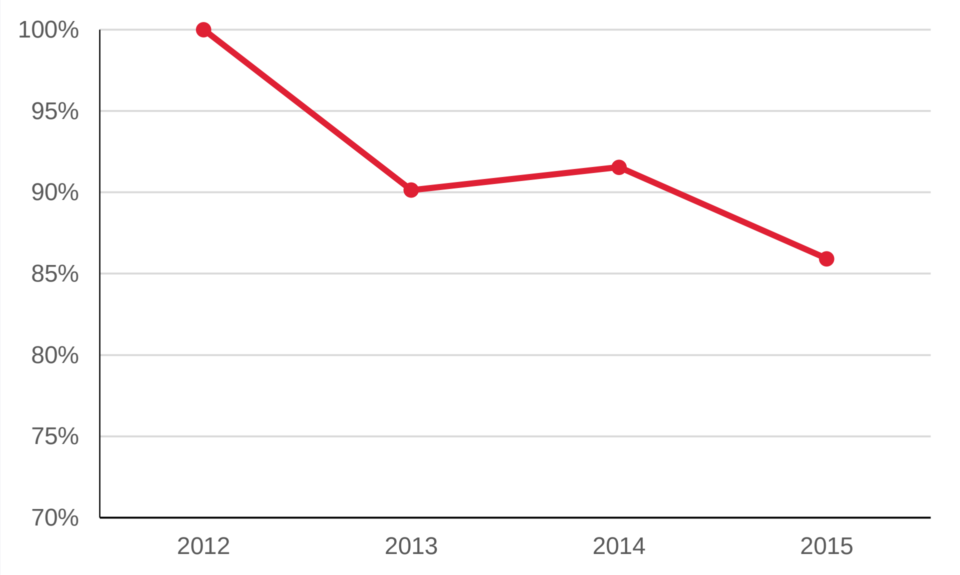
Handling

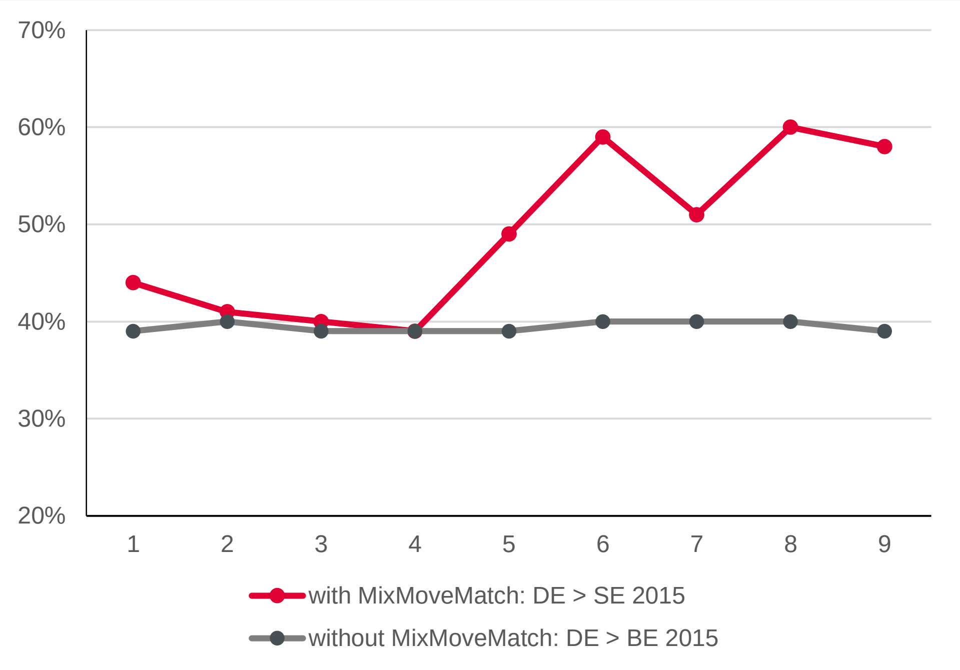
- All added handling is <u>*BAD*</u> as it only adds cost.

Standardisation and colaboration

- Standardisation and Collaboration is not in the best interest of Logistics Service Providers.

Mix Move Match – Effects in practice over one operation





Freight costs evolution during the use of MixMoveMatch.com (index 100%=2012)

Load factor with and without use of MixMoveMatch.com during 9 months in 2015

what
clients say

3M Saved 35% in logistics costs

"3M reduced transport costs by 35% and CO2 emissions by 50% since the MixMoveMatch.com system was launched"

Patrick Van de Vyver

3M EMEA's
logistic operations

DHL become far more flexible and saved a lot of costs

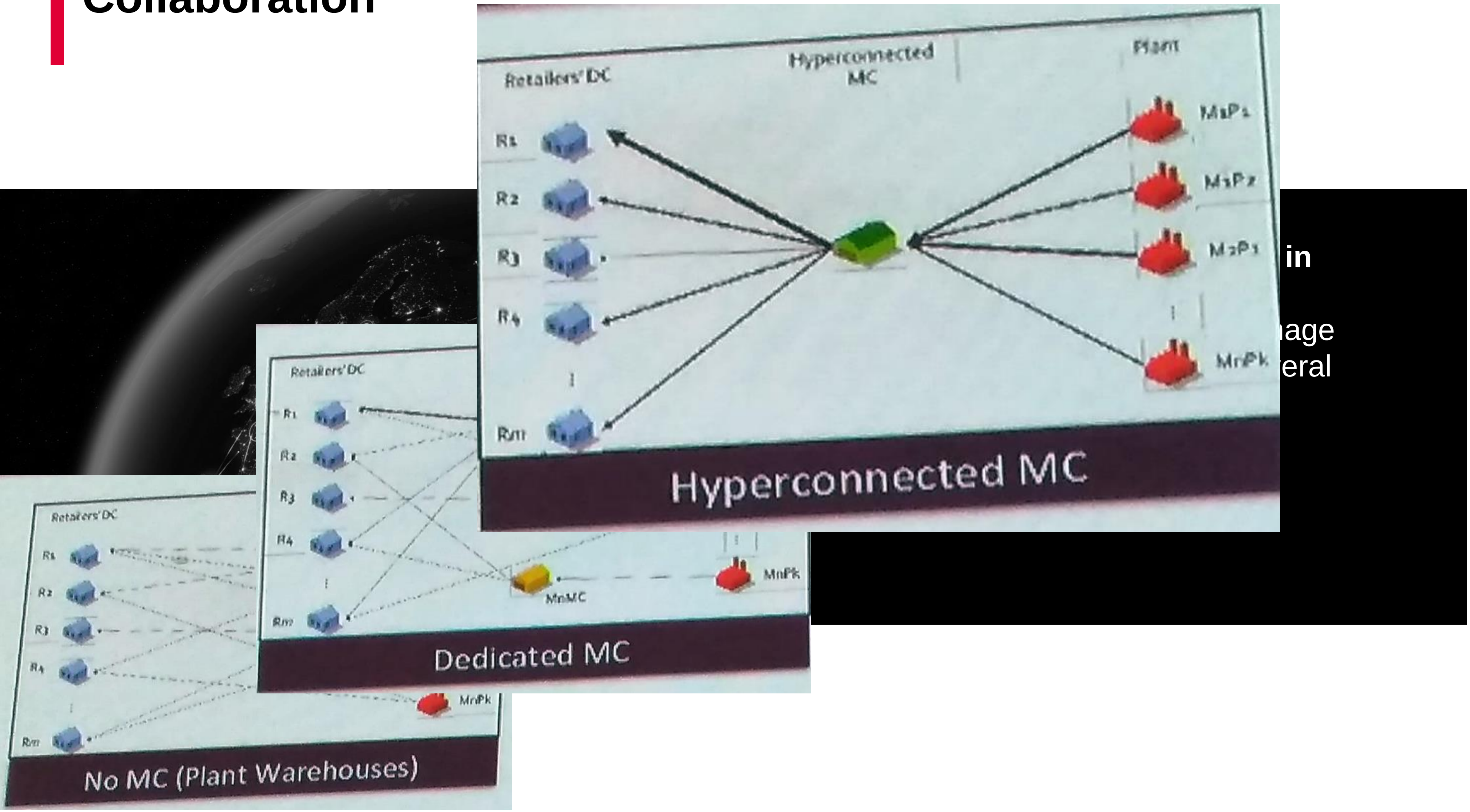
*"Warehousing costs are generally about half of the Transport costs in terms of cost of sales. This is why it doesn't get as much attention as it should. But having warehouses doing various kinds of things that you might not immediately think of as warehousing services allows you to **be far more flexible with your supply chain** and thus **save a lot of costs**."*

.

Jaco Voorspuij

DHL IT lead EMEA
region

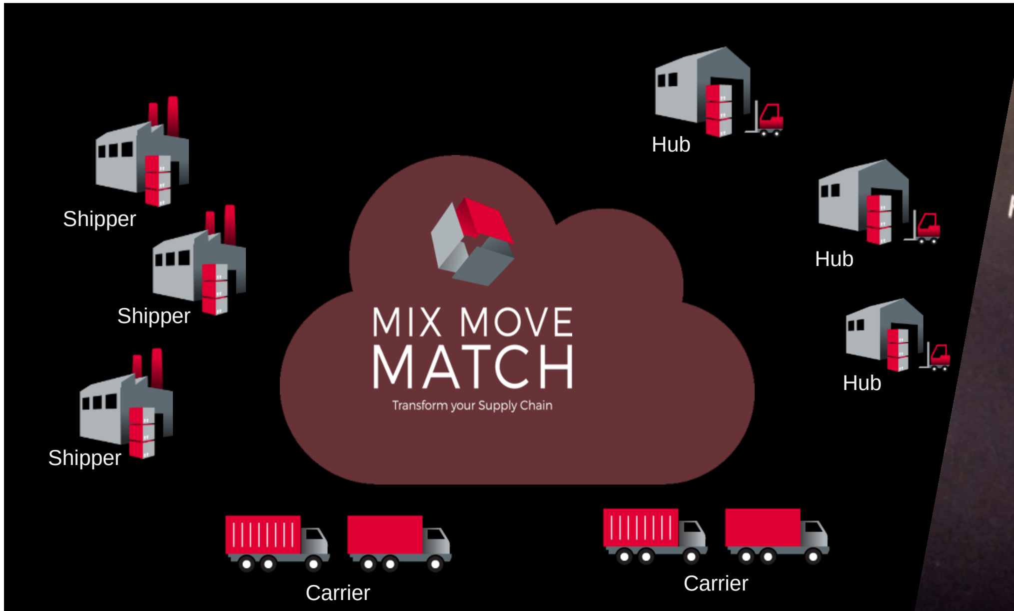
Collaboration



MIX MOVE MATCH
Transform your Supply Chain

MARLO

MixMoveMatch.com in a nutshell



NEWS OF THE DAY: MIXMOVEMATCH.COM AWARDED WITH THE PHYSICAL INTERNER VE

MixMoveMatch.com provides capabilities for:

Shippers

- Horizontal collaboration
- Visibility
- Dashboard
- Rule based fulfillment
- …

Hubs

- x-dock/reconstruction
- Decide next segment
- Optimize use of resources
- Rule based
- …

Carriers

- Optimise movements
- Provide status/POD
- …

Supply Chain Integration

Shipping orders

Tracking and tracing

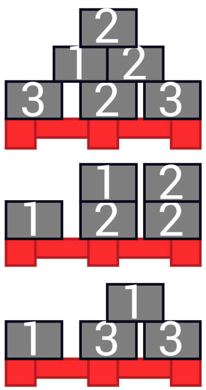
Inventory orders and status

MIX MOVE MATCH
Transform your Supply Chain

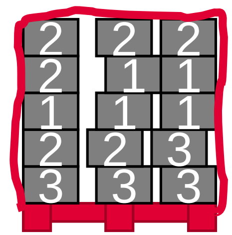
Load Unit Optimisation
The objectives

- the optimization of the load factor in the distribution
- to obtain full transparency of the increasingly fragmented supply chain for all stakeholders while
- keeping the flexibility and scalability on parcel level
- solution available for every player

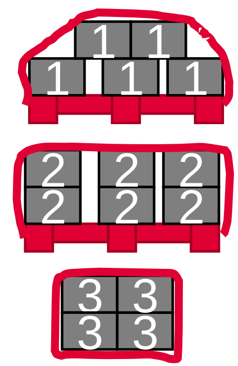
Load Unit Optimisation
The solution



MIX
inbound pickup hub



MOVE
long-haul transport

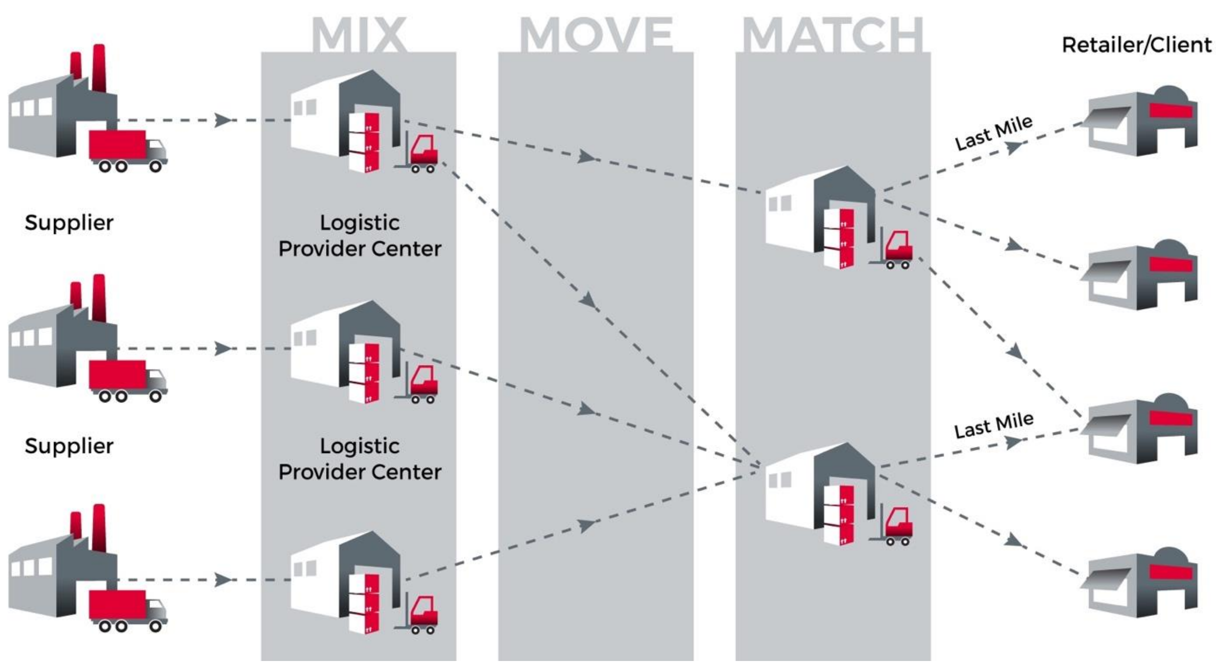


MATCH
outbound distribution hub

The consignments of various shippers on several trucks are consolidated in the hub according to destinations on mixed, high loaded pallets (Mix) and transported furtherone (Move). At the hub close to the destination area, the consignments will be sorted (Match), where also a higher bundling on the last mile can be achieved.

.

Load Unit Optimisation
How does it work?



Combines consignments

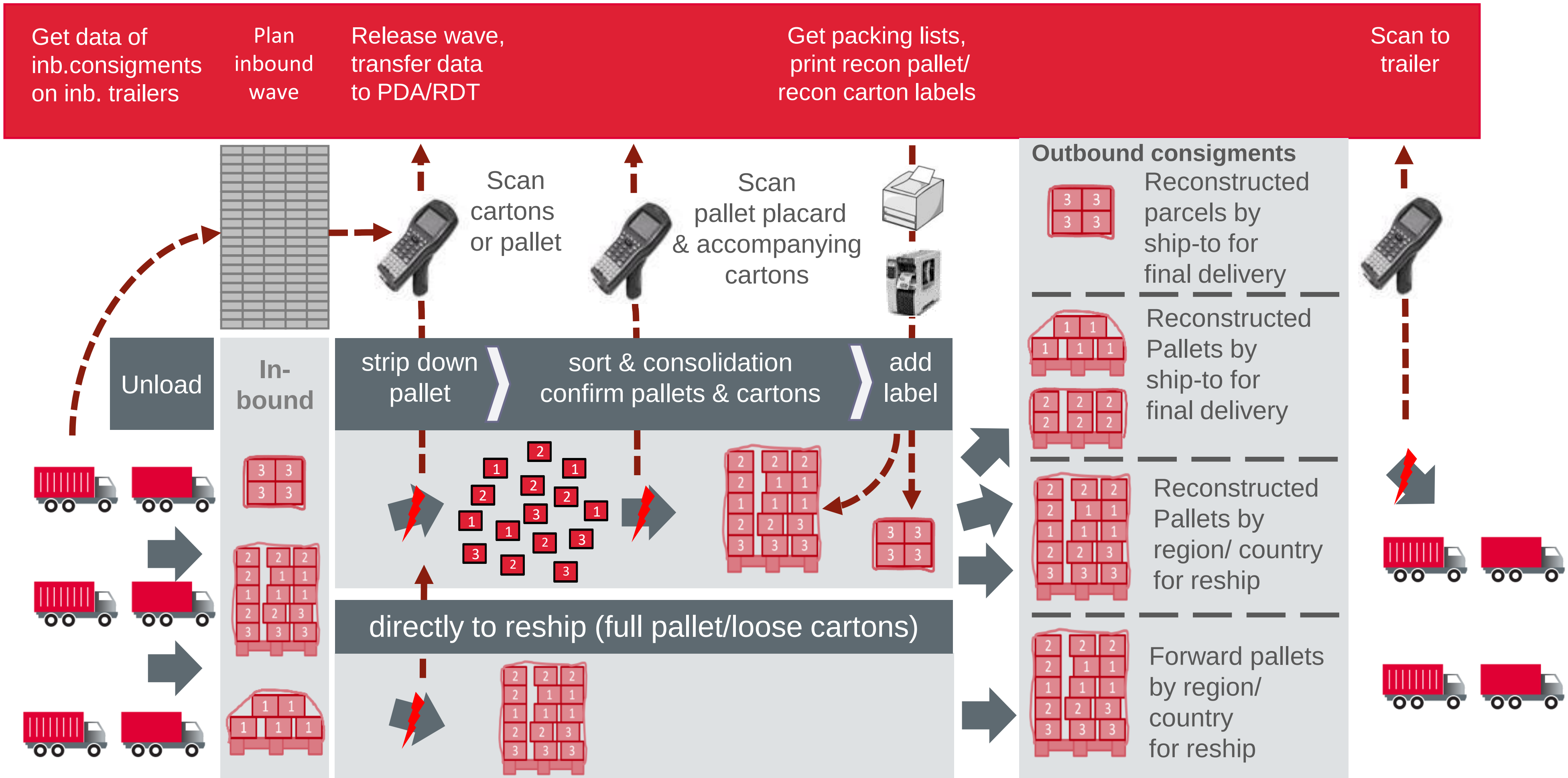
from different suppliers and carriers

…by stripping down and creating next leg

optimized consignments

…on therefore much higher loaded loading units

Load Unit Optimisation
The Process



MixMoveMatch.com work routine

preparation

Preparation of the work area:
pre-sorting area, reconstruction area
placards for instant visualization

pre-sorting

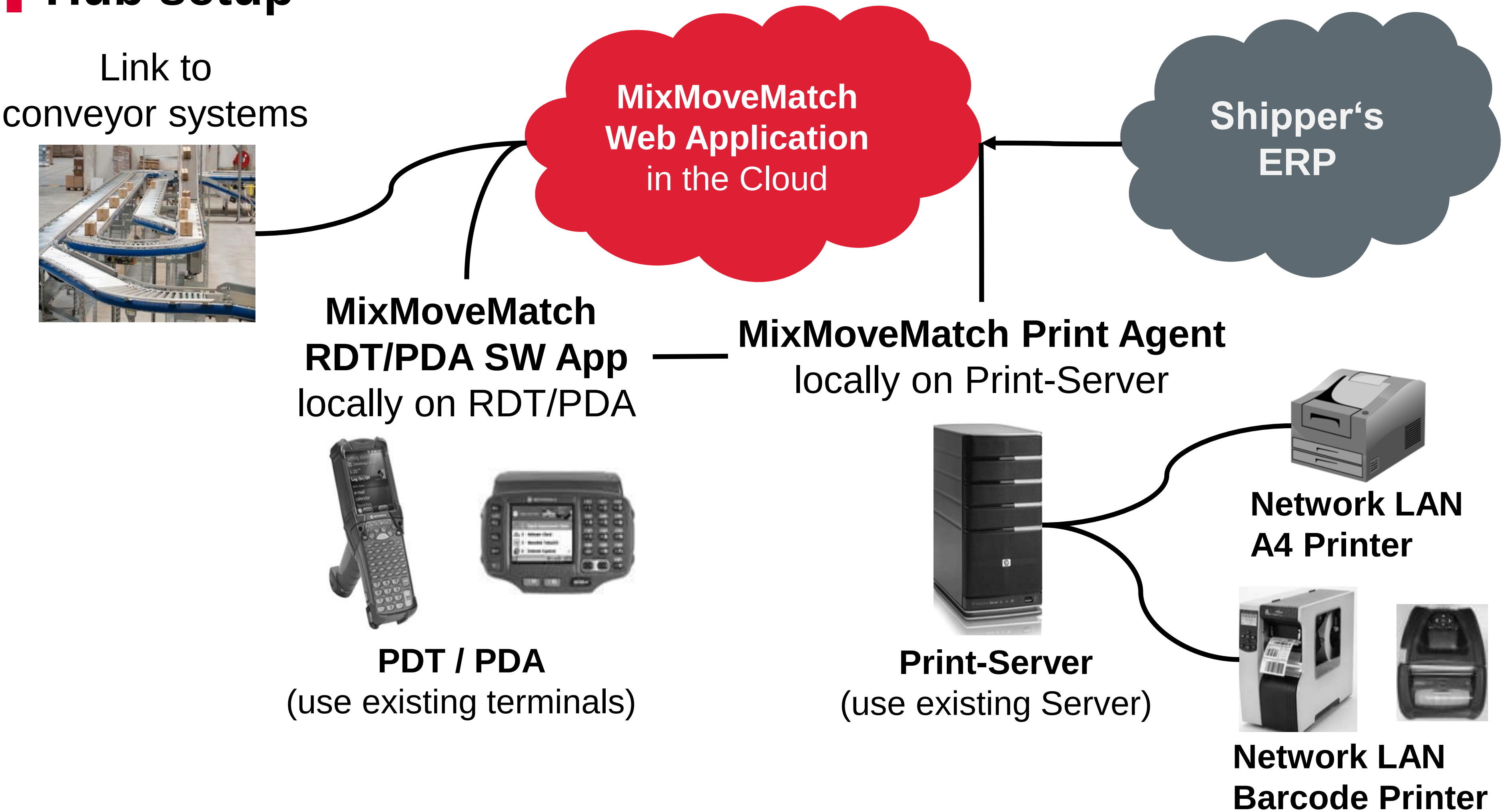
Dismantling of inbound pallets,
pre-sorting to reconstruction
or parcel services

reconstruction

Reconstruction to new consignment,
consisting of packages from several
inbound consignment

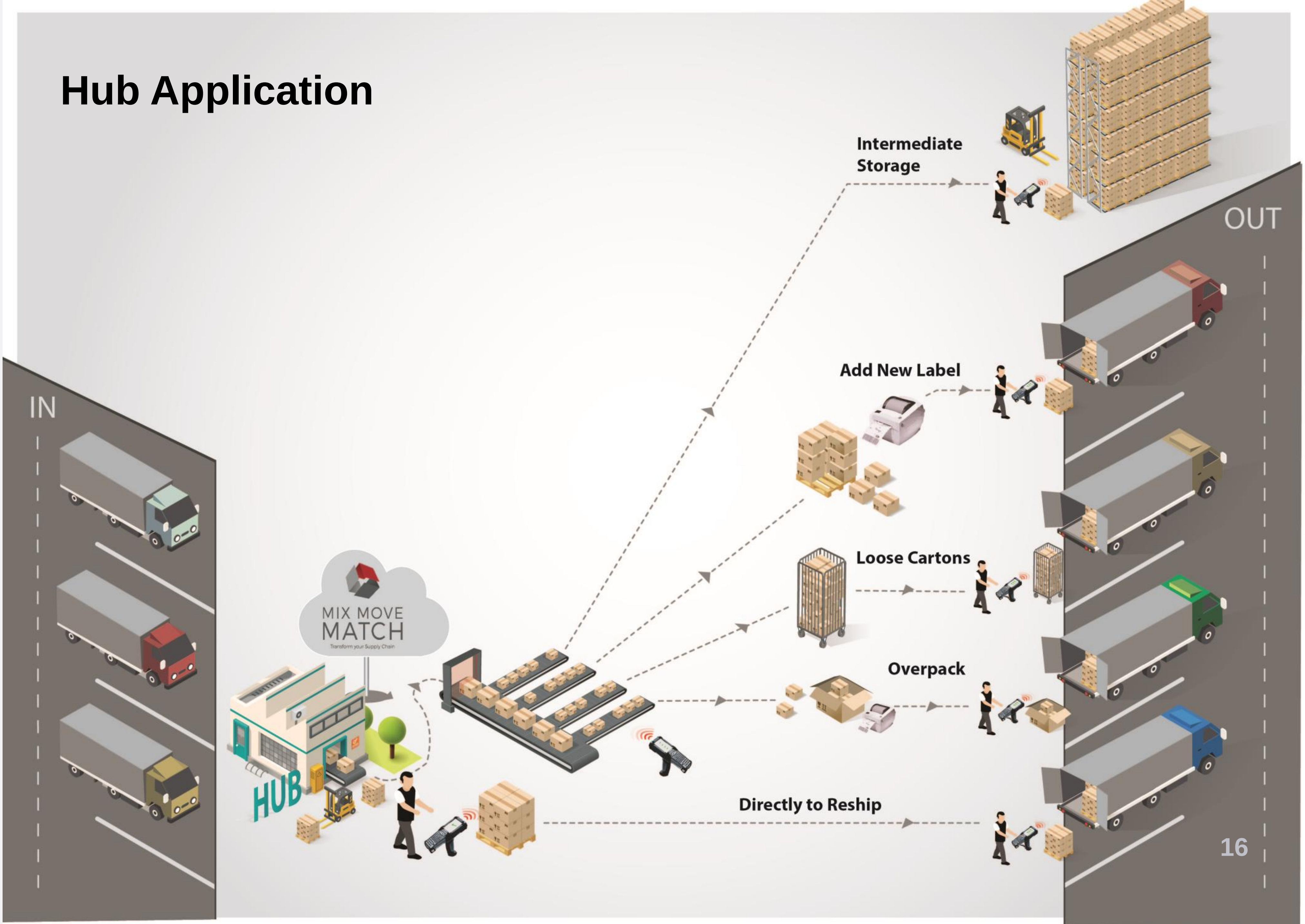
Load Unit Optimisation
The principle: unique identification

Load Unit Optimisation Hub setup

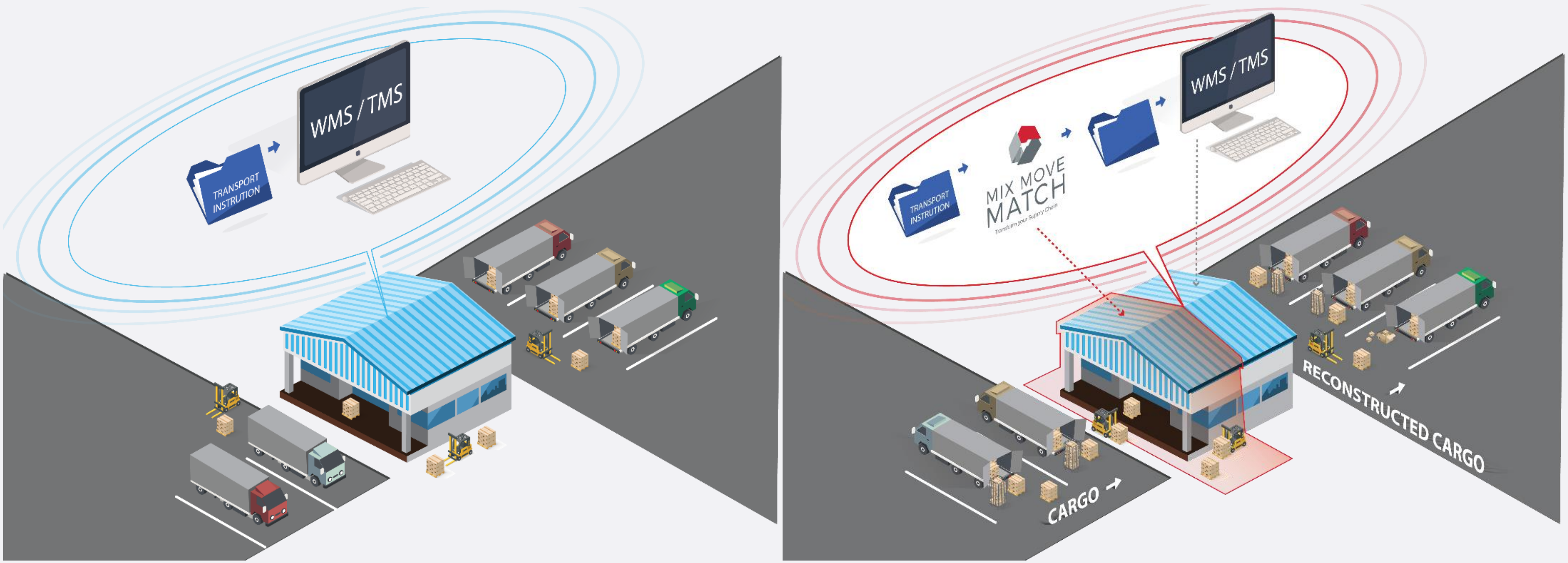


RDT = Radio Data Terminal
PDA = Personal Digital Assistant

Hub Application



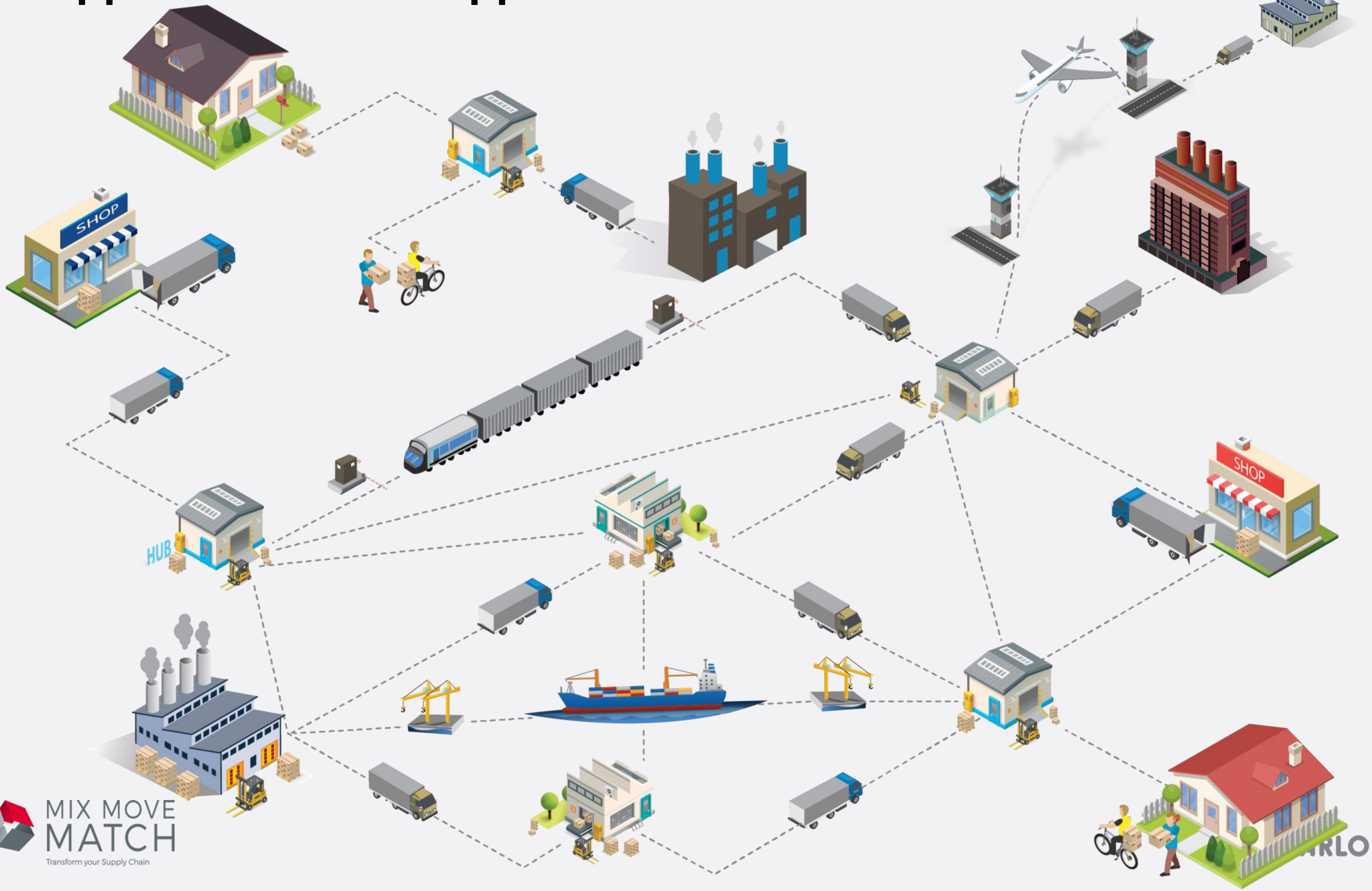
Introduced without changes to existing infrastructure



MIX MOVE MATCH
Transform your Supply Chain

MARLO

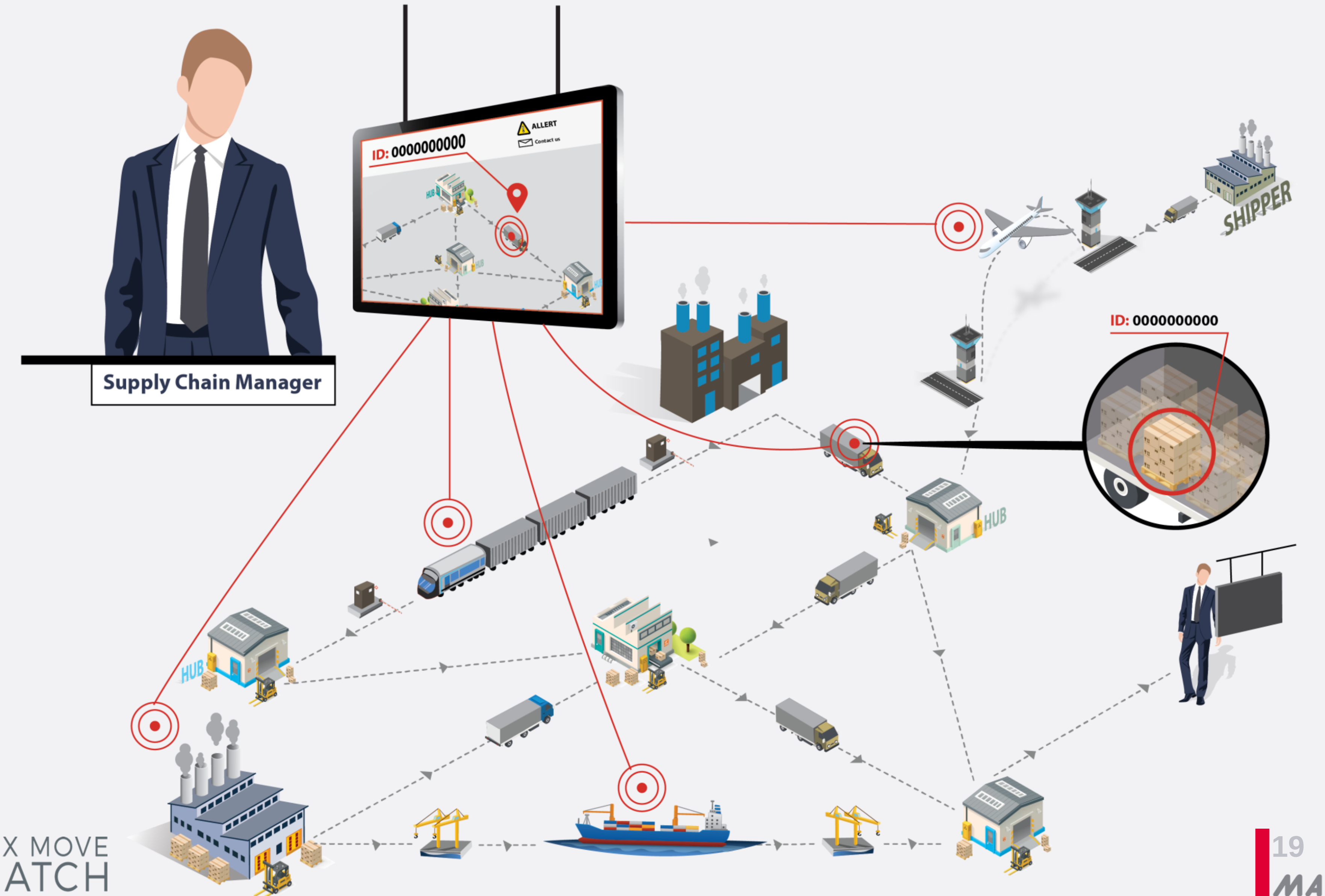
Shipper and Carrier Application



MIX MOVE MATCH

Transform your Supply Chain

Visibility Application



Dashboard

30 terminals
20+ city hubs

2.000.000 +

Items shipped per month

60.000 +

More than 60.000 distinct products are handled with MixMoveMatch.com

19

Implemented in 19 countries

MIX MOVE MATCH
Transform your Supply Chain

MARLO

MixMoveMatch.com implementation

17 countries

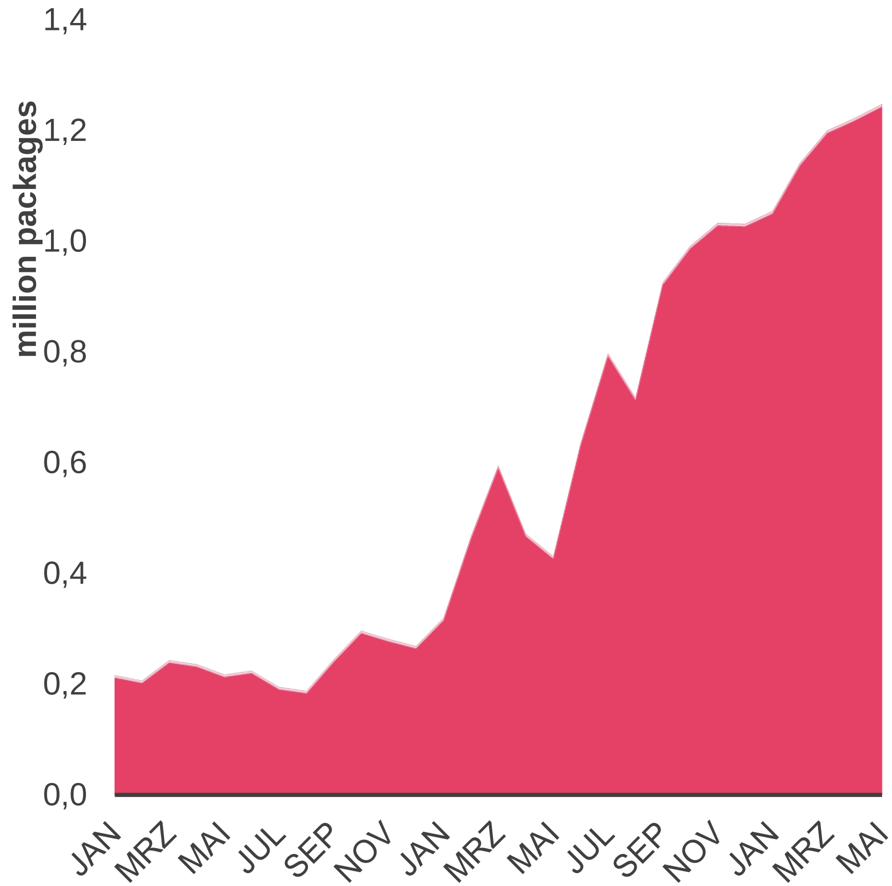
MixMoveMatch.com is now operating in 17 countries

1.5 million / month

Over 1,5 million packages are processed monthly

60.000 +

More than 60.000 products handled



MIX MOVE MATCH

Transform your Supply Chain

MARLO

reference shippers and logistic providers are using it

… and many others

MixMoveMatch.com example: 3M

The 3M case study

- ✓ Before the distribution took place on customer specific pallets right from the 50 factories or distribution centres causing a load factor of about 31% in average only.
- ✓ By applying the principle of MixMoveMatch.com the load factor increased to more than 70% in average.
- ✓ During the period of the ongoing operation of the rule based optimisation of MixMoveMatch a steadily increasing load factor, obviously being a learning curve, could be observed.
- ✓ In the first year of operation alone MixMoveMatch.com 3M saved about 5 million truck-kilometer or rather 10% of their transport related CO_2 emissions
- ✓ According to 3M, MixMoveMatch.com now originates approx. 35% savings in total logistics costs

MixMoveMatch.com
Physical Internet Provider

nuno.bento@marlo.pt
+ 351 96 851 67 41
tomasz.dowgielewicz@marlo.no
+48 601 415 321
roland.findrik@marlo.no
+49 721 860 18 60

MARLO