



Physical Internet

Efficient Sustainable Logistics



An Open Innovation Initiative

3rd International Physical Internet Conference

From Dedicated to Hyperconnected Distribution Systems: An Optimization-Based Approach

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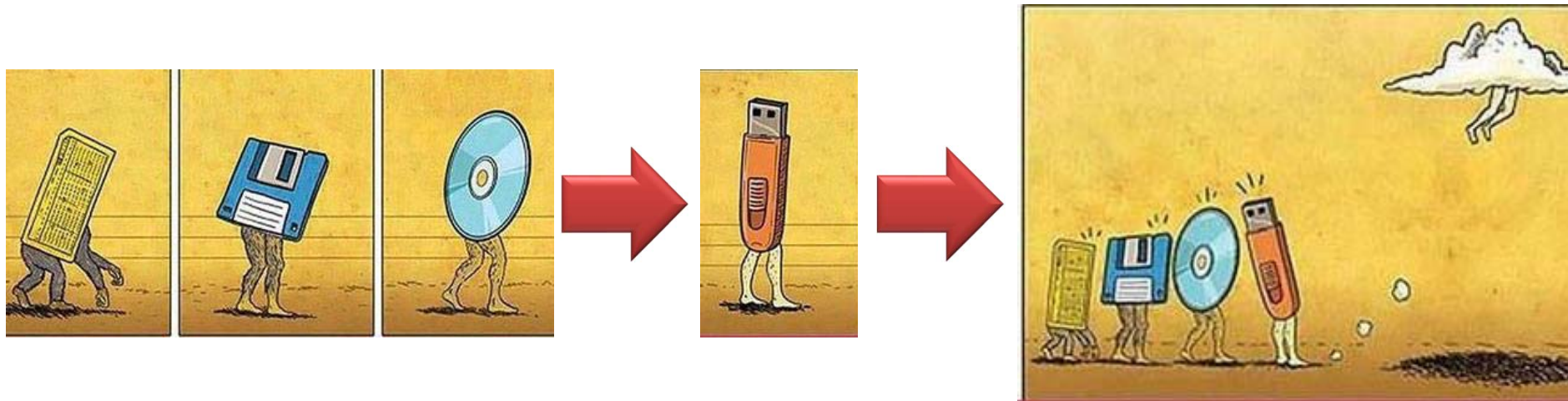
Presentation plan

- Introduction to Hyperconnected Distribution
- Challenges & Framework
- Distribution Design Models
- Illustrative Cases (3 Companies and 6 Companies)
- Concluding Remarks and Open Discussion



Introduction to Hyperconnected Distribution

Evolution of storage and distribution



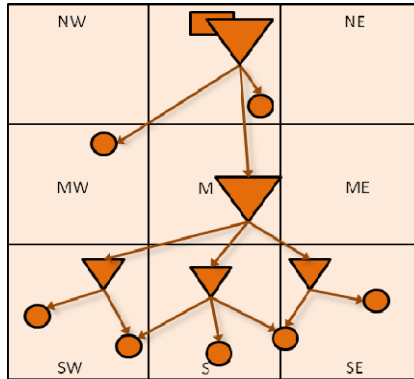
The evolution of data storage

<http://www.tumblr.com>

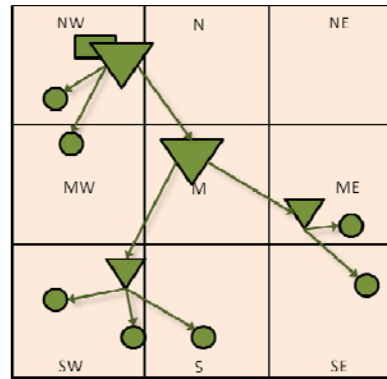


Introduction to Hyperconnected Distribution

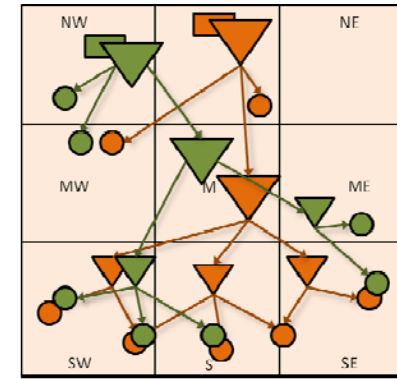
Evolution of storage and distribution



Business A, dedicated distribution network



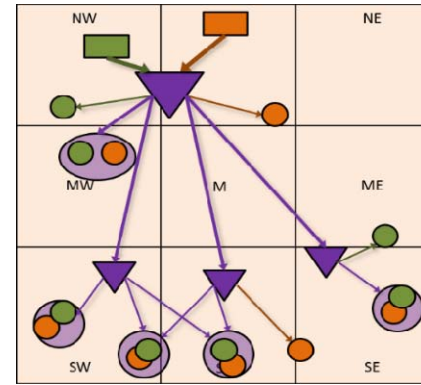
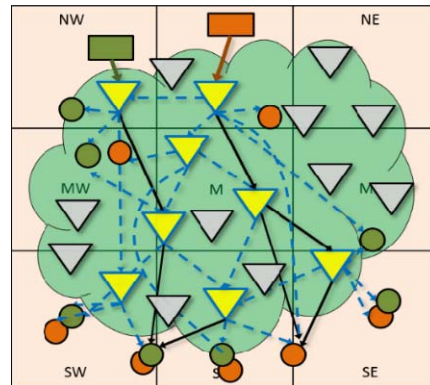
Business B, dedicated distribution network



A & B, disconnected distribution networks



A & B, hyperconnected distribution webs



A & B, collaborative distribution web

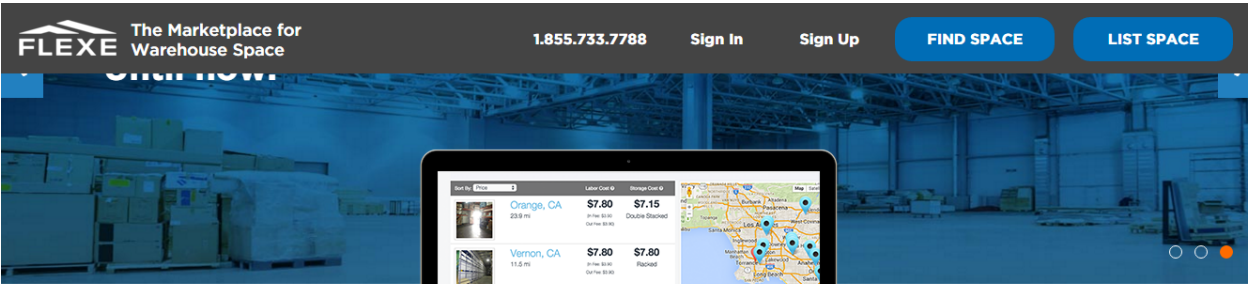
Plant, Company A	DC, Company A	Market, Company A	Plant, Company B	DC, Company B	Market, Company B	Flow, Company A	Flow, Company B	Collaborative flow	Jointly supplied markets	Collaborative DC	Flow via Mobility Web	PI open DC cloud	Exploited PI open DC	Unexploited PI open DC



Introduction to Hyperconnected Distribution

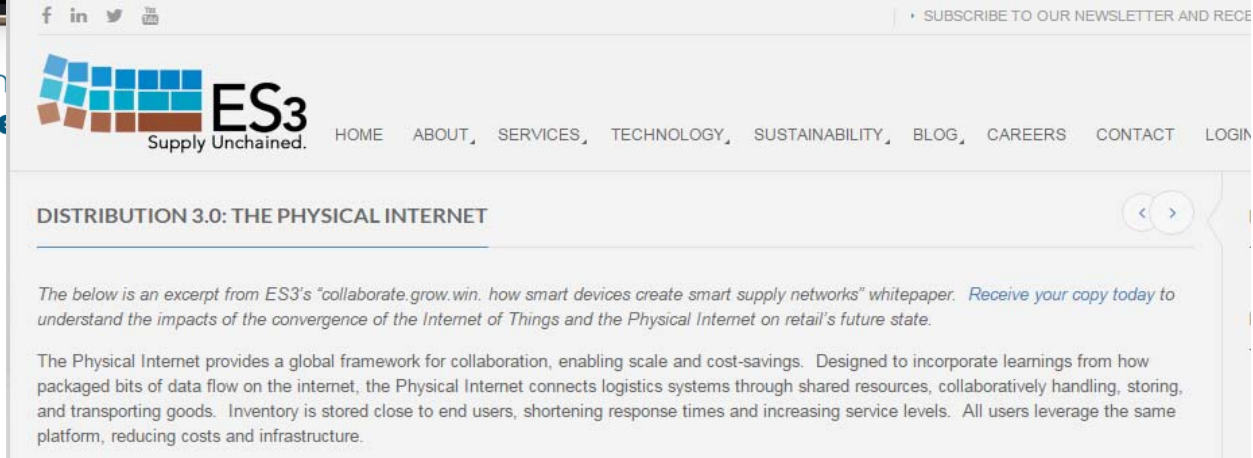
Evolution of storage and distribution

<https://www.flexe.com/>



<http://www.es3.com/>

FLEXE connects
capacity where





Challenges

- ❑ Why do we need a Hyperconnected distribution strategy ?
 - Omni Channel Distribution
 - E-commerce & Faster Service Levels
 - Dealing with Uncertainty & Resilience
 - Dynamic Stock Deployment (Velocity)
 - Potential of Automation, Data and Analytics

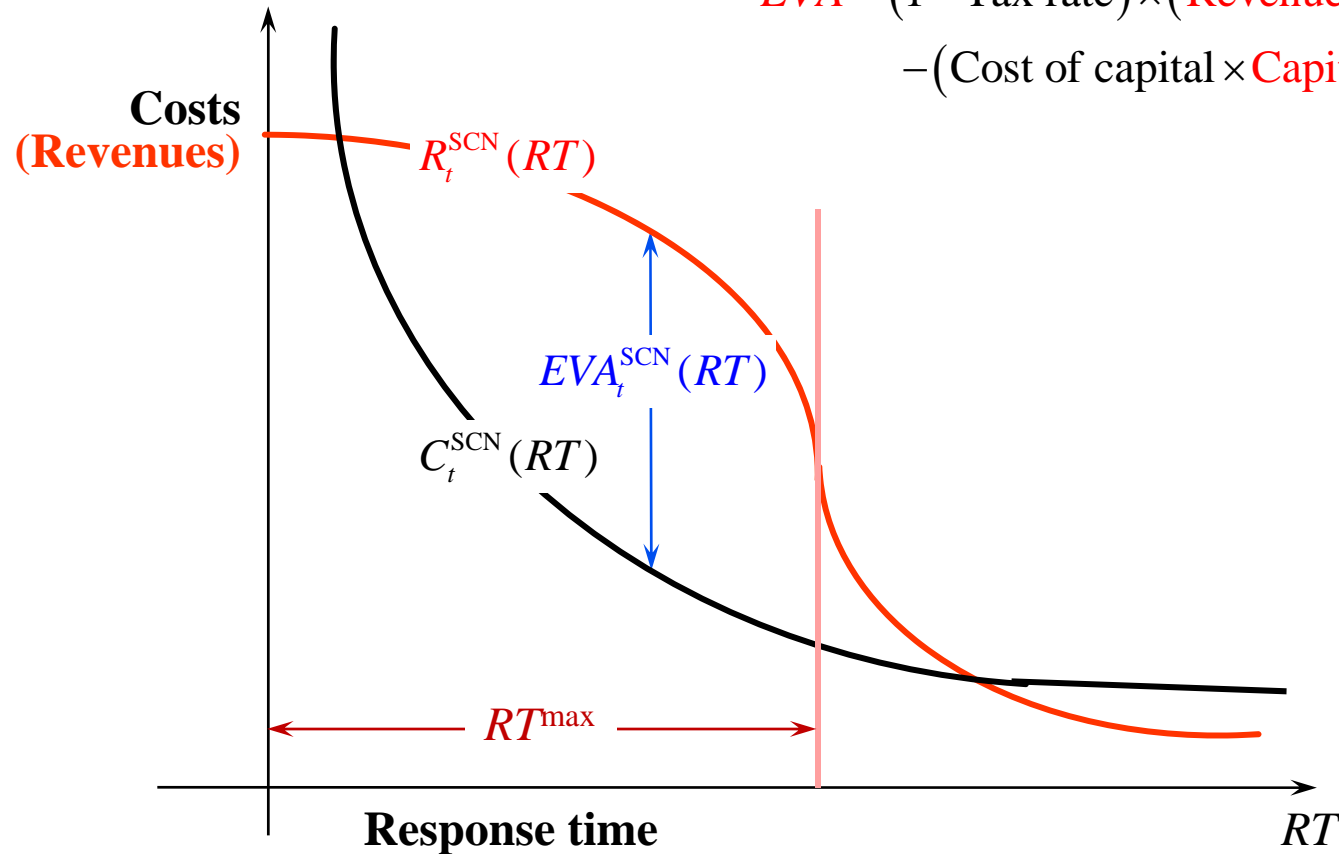
- ❑ What is the magnitude of the potential **economic** performance gain by exploiting Hyperconnected Distribution?
 - Scope: Investigate at a **strategic level** the potential for **economic performance gain** from exploiting hyperconnected distribution system.



Introduction to Hyperconnected Distribution

➤ **Network Design drives Revenues**

$$EVA = (1 - \text{Tax rate}) \times (\text{Revenues} - \text{Expenses}) \\ - (\text{Cost of capital} \times \text{Capital employed})$$

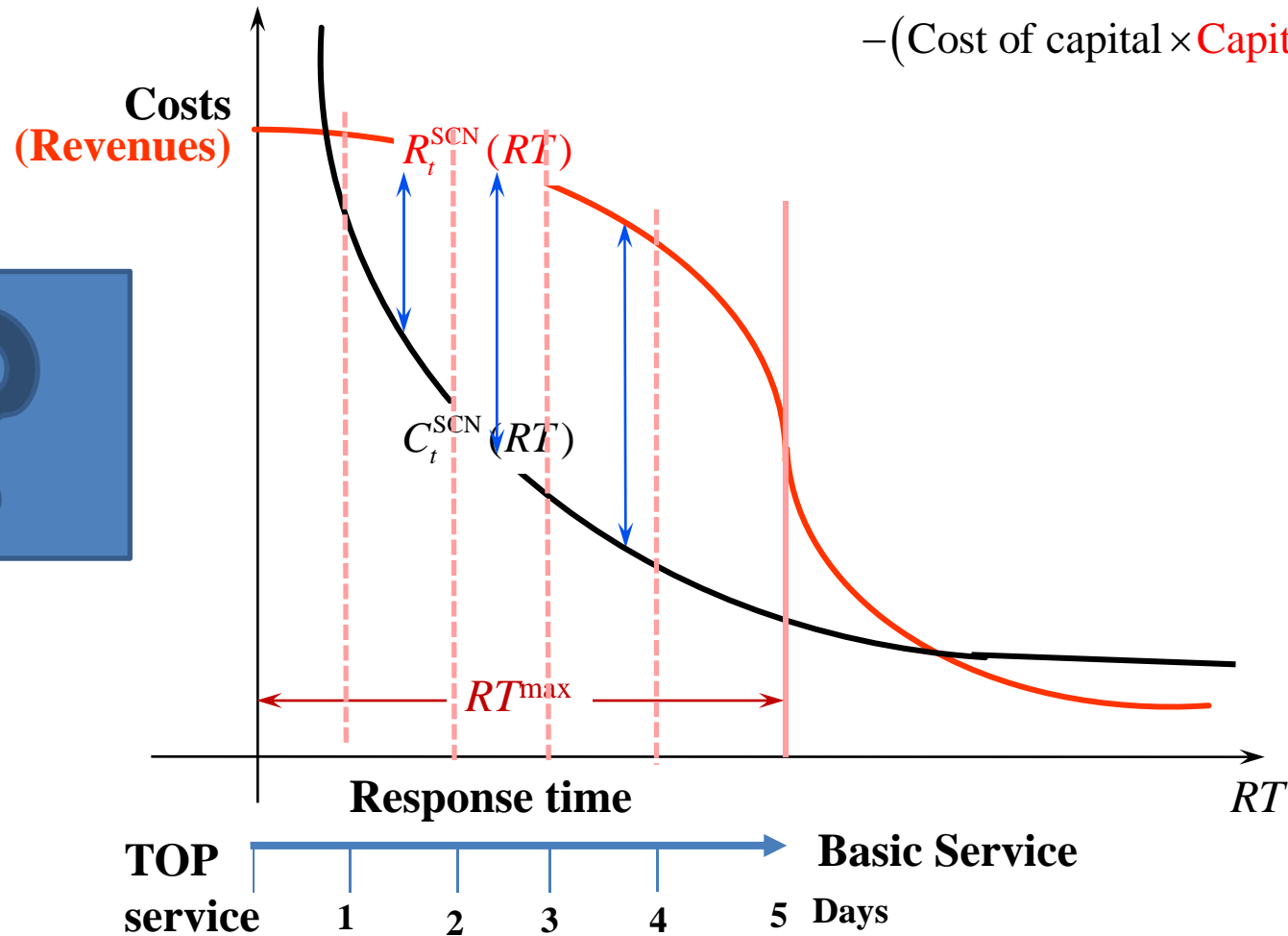




Introduction to Hyperconnected Distribution

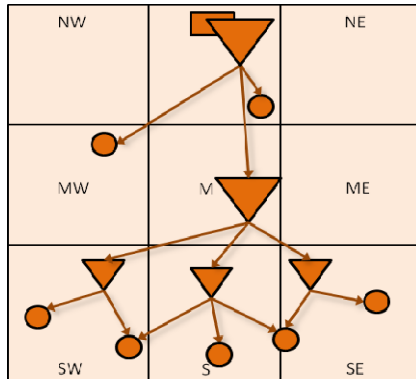
- Network Design drives Revenues

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Introduction to Hyperconnected Distribution



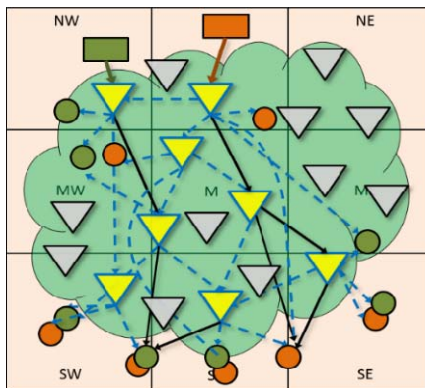
Business A, dedicated distribution network

➤ **Distribution Network Design drives Revenues**

- Long-term Planning Horizon (3 to 5 years)
- Design a fixed distribution schema (configuration).
- Own/rent a number of DCs on 1 or more echelons
- Product-Market Selection (target a response time)
- Optimize flows (a fixed mission for each DC)

Operate

[1 DC – 20 DCs]



A& B, hyperconnected distribution webs

➤ **Distribution Web Strategy drives Revenues**

- Long-term/mid-term Planning Horizon (1 to 2 years)
- Design a flexible distribution schema (configuration).
- Own/rent/share/exploit a distribution web
- offers are modulated by product-market (Prime response time)
- Plan to deploy flows (a variable mission for each DC)

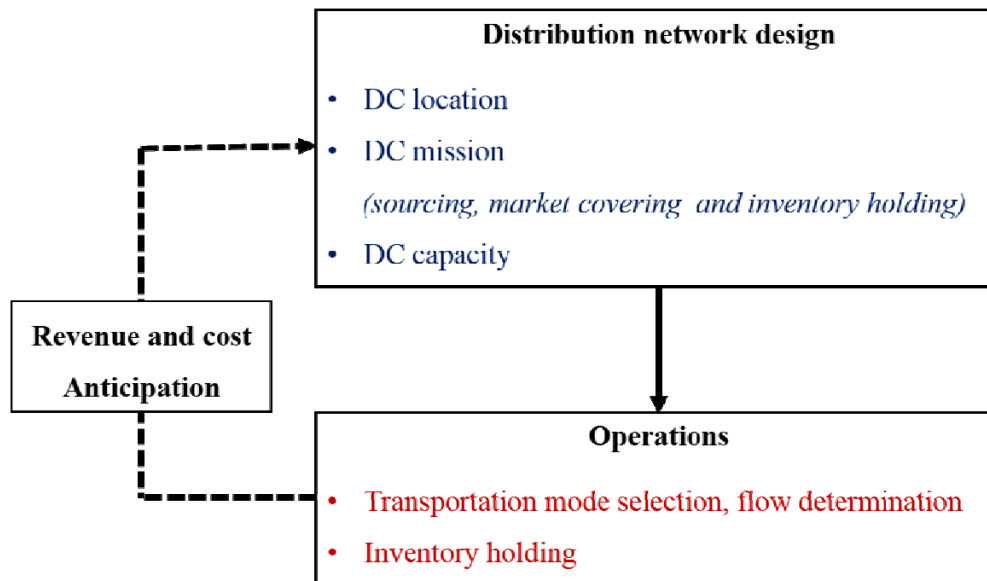
Operate

$N \gg 20$ DCs

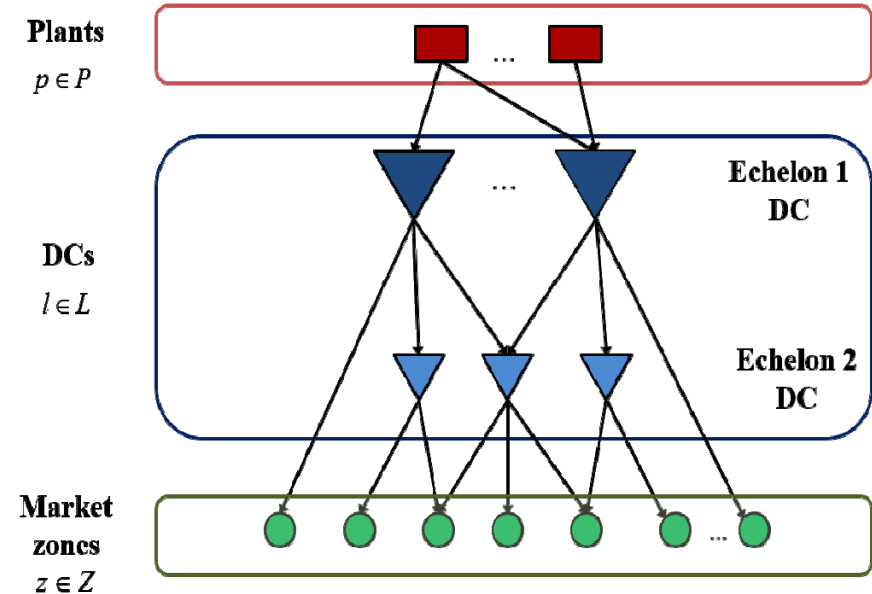


Distribution Network Design Models

Core modeling approach



An anticipation-based modeling approach



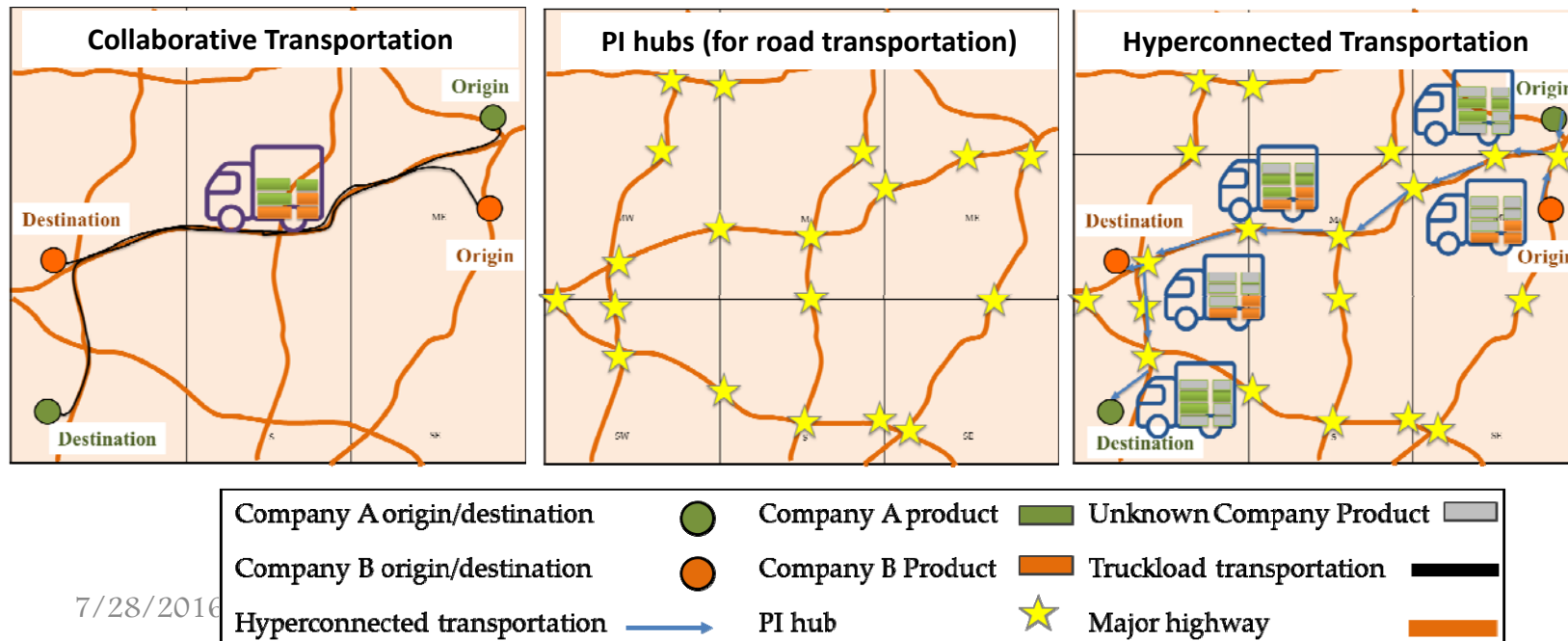
The distribution network structure

Klibi, W., Martel, A., & Guitouni, A. (2015). *The impact of operations anticipations on the quality of stochastic location-allocation models*. Omega.



Transportation Economies of scale

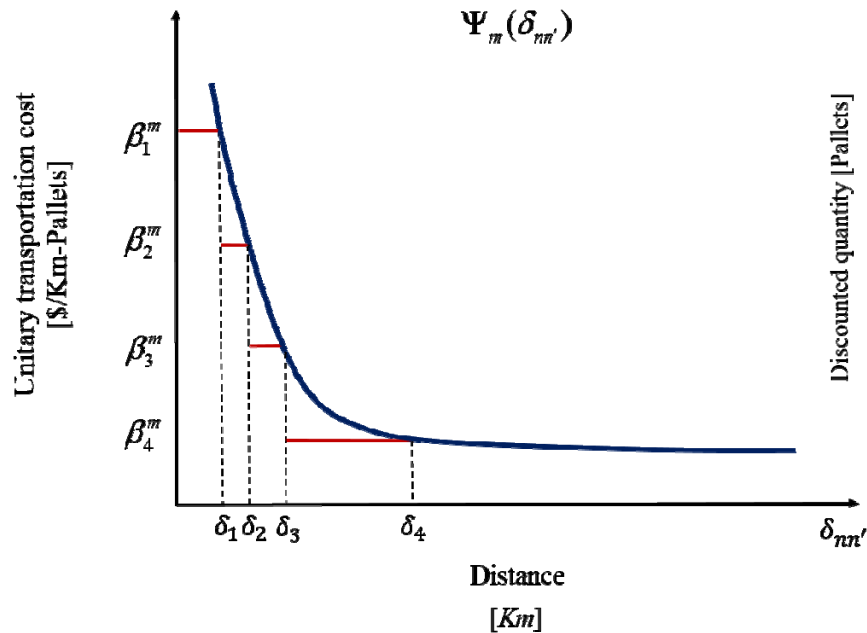
- Almost **one-third** of kilometers traveled by freight transport vehicles are run **empty** (McKinnon, 2000) ,
- The **average utilization rate** of commercial **trucks** is almost **60%** (Sarraj et al., 2014)
- One of the goals of **PI** is to enhance the quality of life for logistics workers such as truck drivers **not to have drivers travel more than a single-day distance** from their hometown



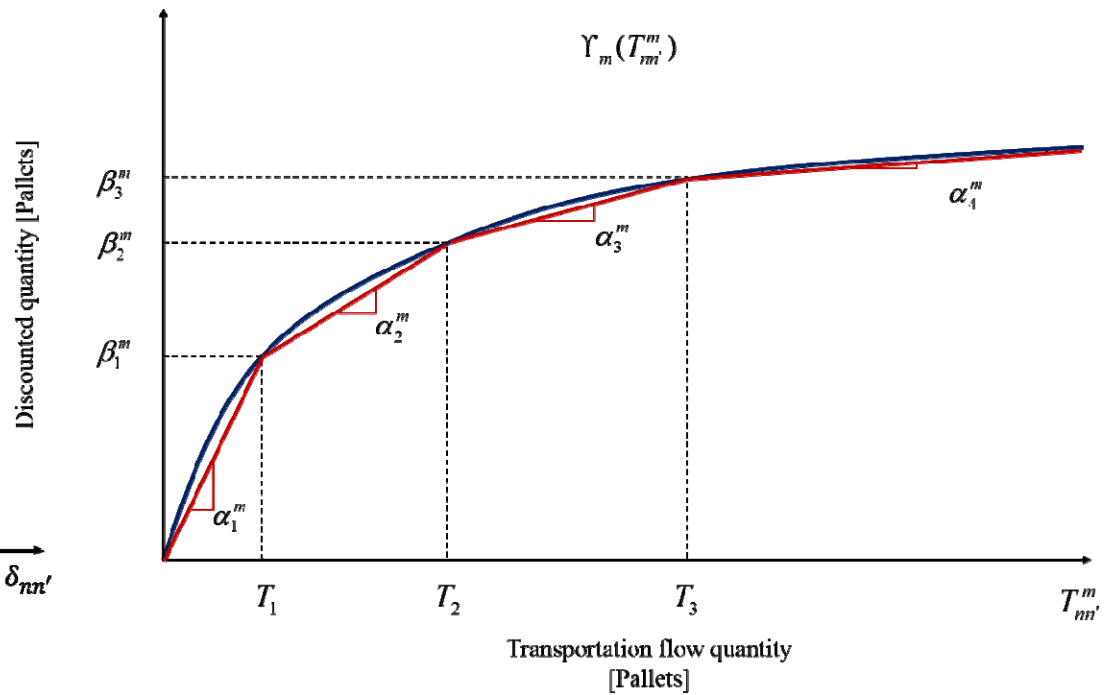


Transportation Economies of scale on distance and quantity

Behavior of the unitary transportation cost as a function of distance



Discounted transportation flow as a function of quantity



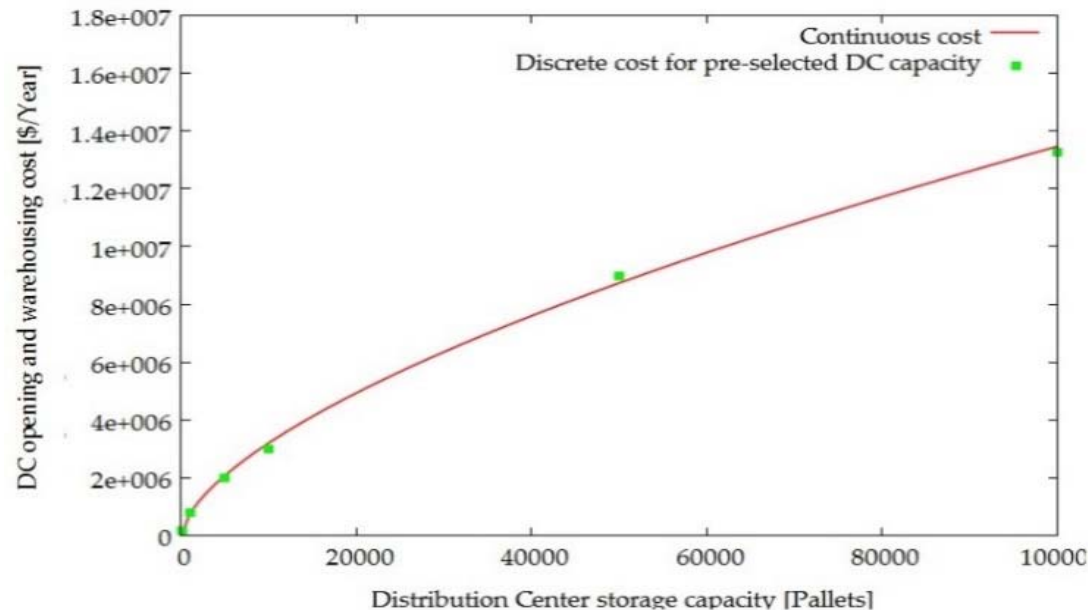


Distribution Network Design Models

Hyperconnected distribution system

Similar to the core model subject to differences in **parameter** and **cost settings** related to the **DCs** and **shipment mode**

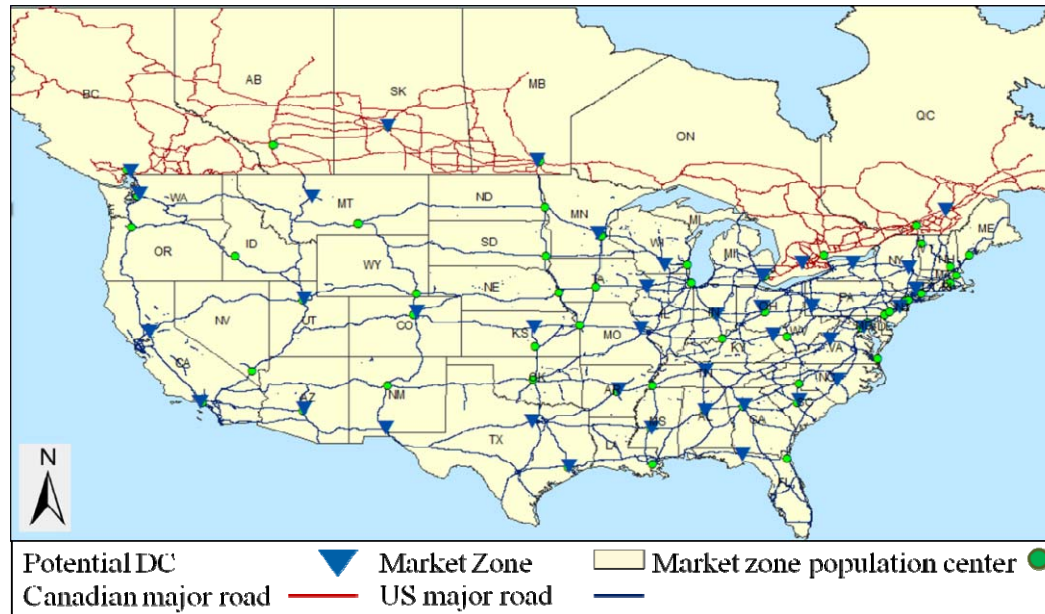
- Geographical location of **hyperconnected DCs** **remains the same**
- Implementation of the **highly advanced modular technologies** in open DCs
- Extremely efficient material handling operations





Business Case 1

- Set of **3 business samples**
- **Single-product**
- Serving US and Canada markets
- Nodes include various subsets of **40 potential DCs** and **55 market zones**
- Annual throughput from 60 000 to 155 000 Pallets/Year



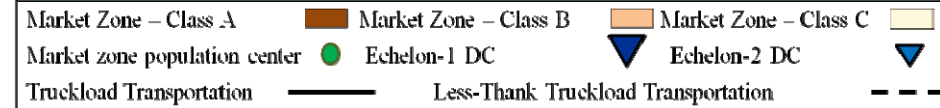
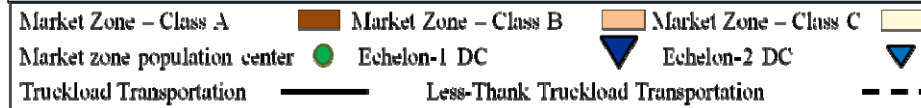
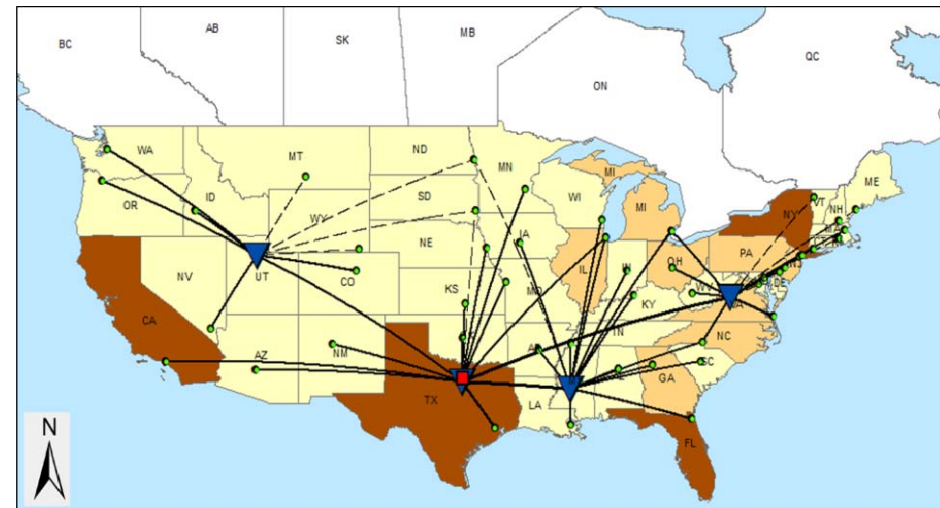
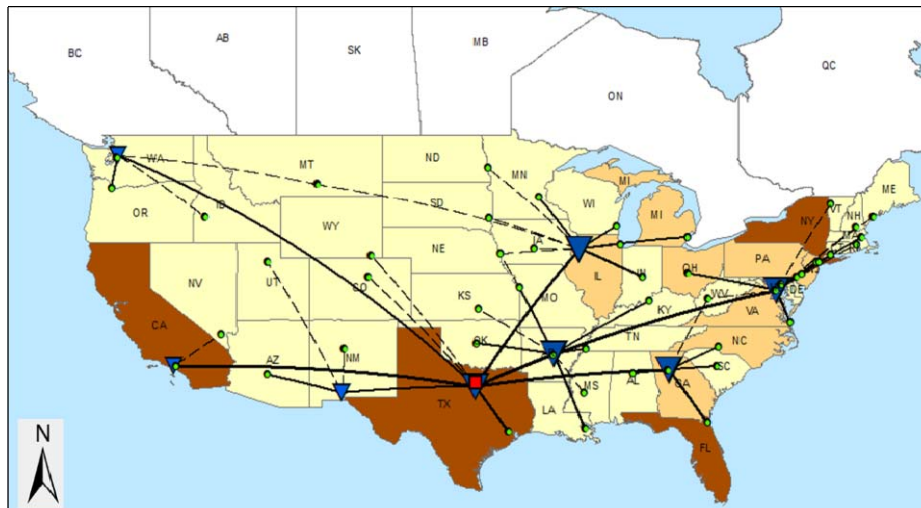


Numerical Experimentation

Distribution Network Topology- Dedicated distribution and transportation

Top service level

Basic service level



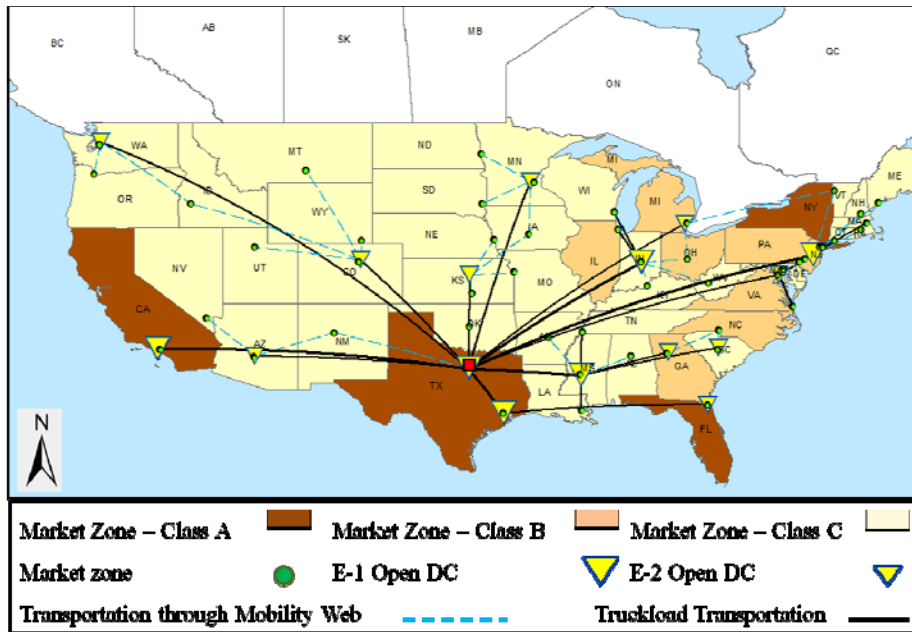
Service Level	Total Distribution Cost [M\$/Year]	Number of DCs (e1, e2)	TL/MTL %- LTL %
Top	66.3	8 (5,3)	95% - 5%
Basic	58.8	4 (4,0)	98% - 2%



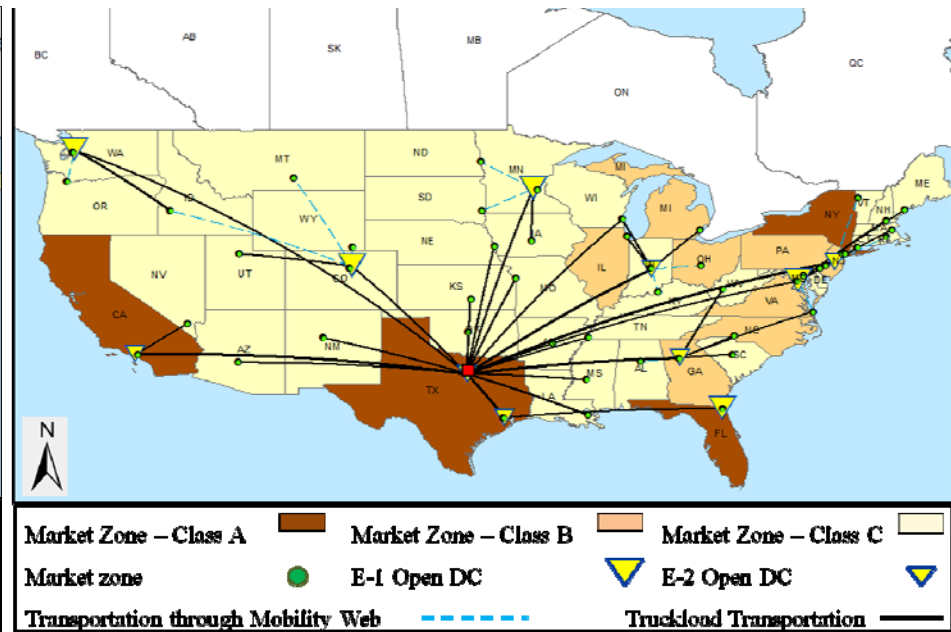
Numerical Experimentation

Distribution Network Topology- Hyperconnected distribution and transportation

Top service level



Basic service level

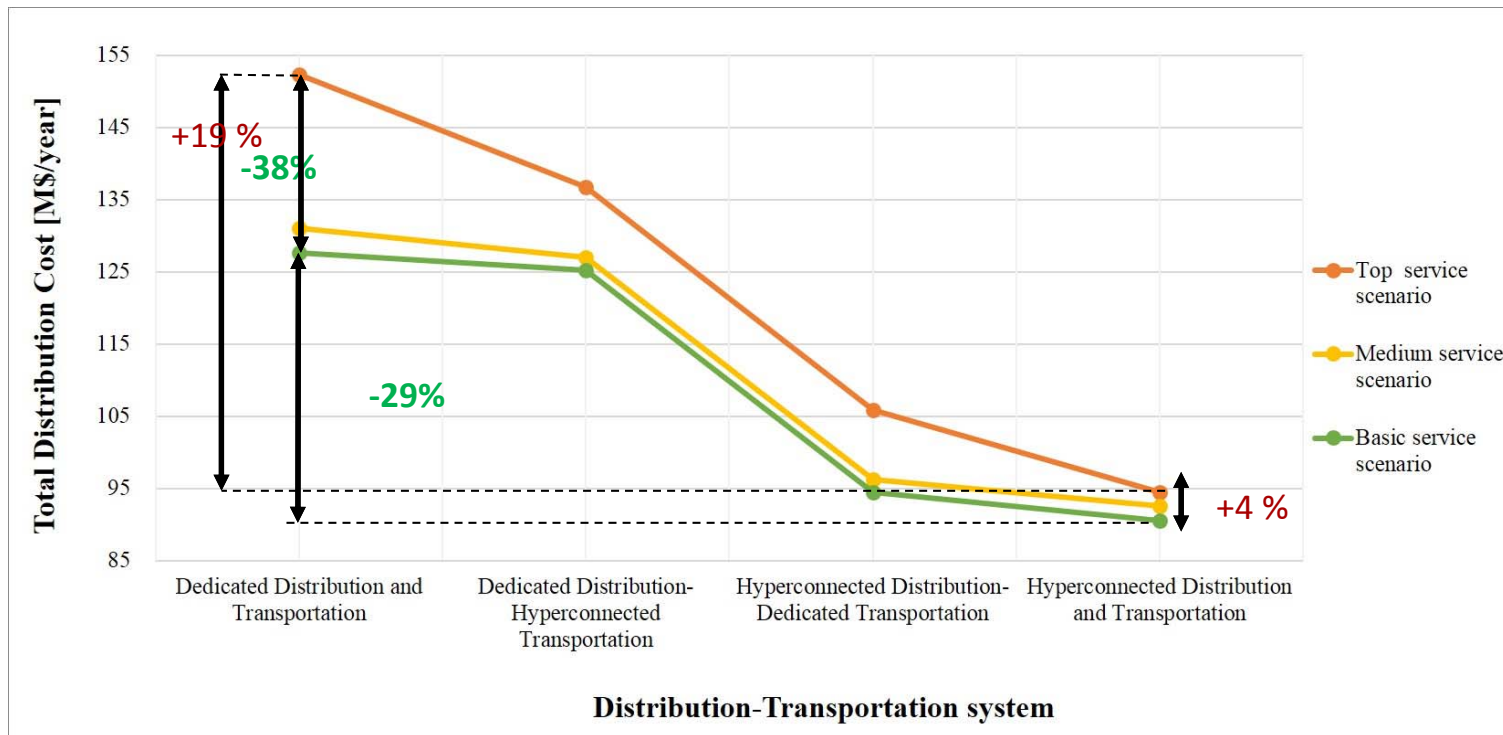


Service Level	Total Distribution Cost [M\$/Year]	Number of DCs (e1, e2)	TL/MTL %-MW%
Top	43	16 (6,10)	60% - 40%
Basic	42.3	14 (5,9)	66% - 34%



Numerical Experimentation

Collective economic performance gain

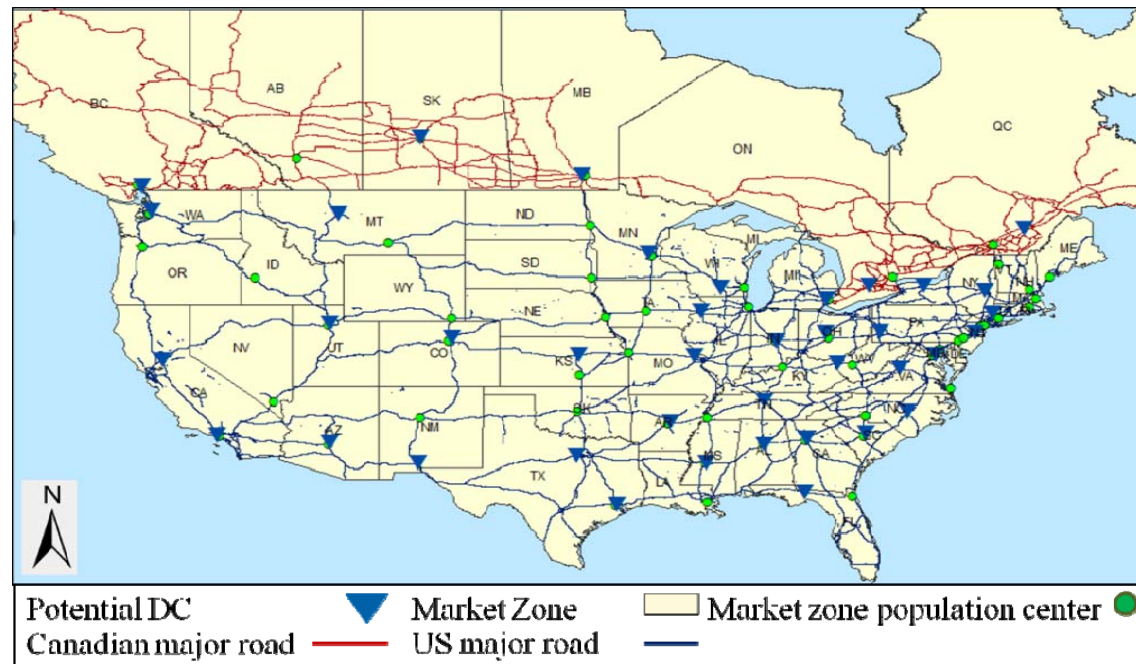


Collective total distribution cost of three businesses cases for each distribution system responding to three service scenarios



Business Case 2

- Set of **6 business samples**
- **Single-product**
- Serving US and Canada markets
- Nodes include various subsets of **40 potential DCs** and **55 market zones**
- Annual throughput from 13 000 to 500 000 Pallets/Year





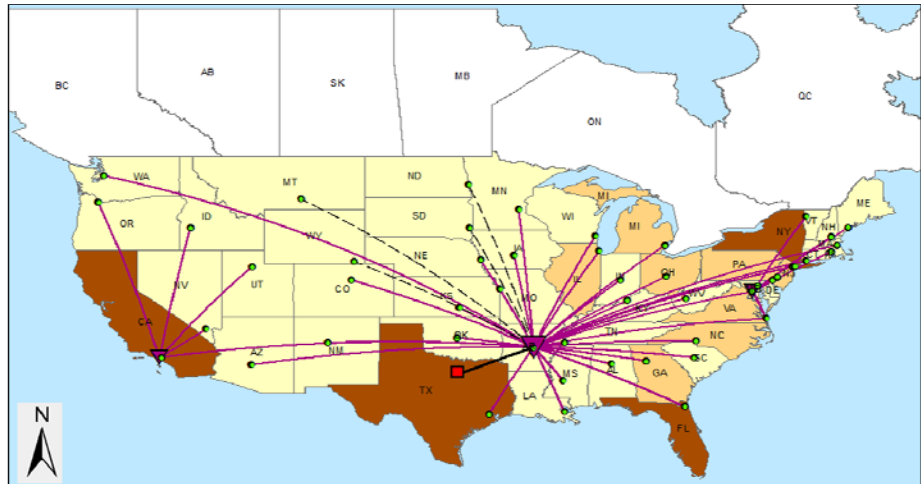
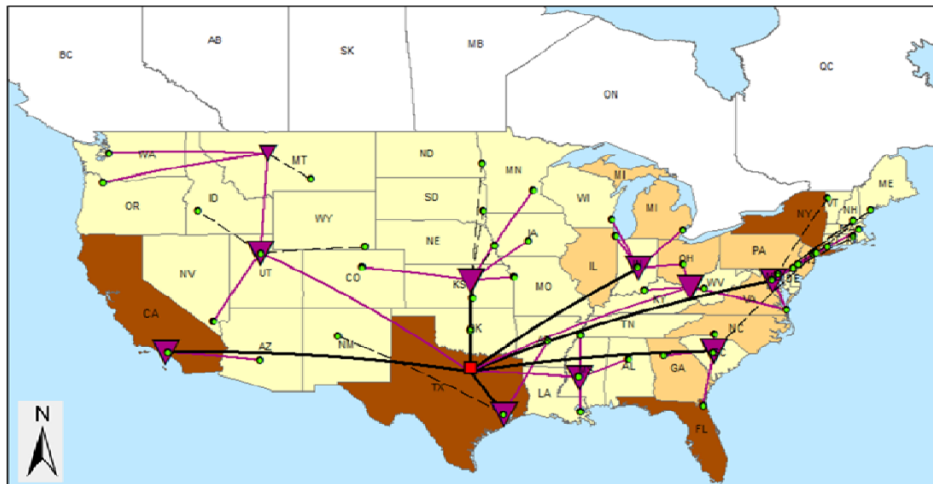
Numerical Experimentation

Distribution Network Topology- Collaborative

Average throughput business sample (155 000 Pallets/Year)

Top service level

Basic service level



Market zone- Class A Market Zone - Class B Market zone- Class C Market zone center
 E-1 collaborative DC E-2 collaborative DC
 Collaborative Truckload transportation Less-Thank Truckload Transportation

Market zone- Class A Market Zone - Class B Market zone- Class C Market zone center
 E-1 collaborative DC E-2 collaborative DC
 Collaborative Truckload transportation Less-Thank Truckload Transportation

Service Level	Total Distribution Cost [M\$/Year]	Number of DCs (e1, e2)	TL/MTL %- LTL %
Top	59.7	10 (6,4)	94% - 6 %
Basic	53.8	3 (1,2)	100% -0 %



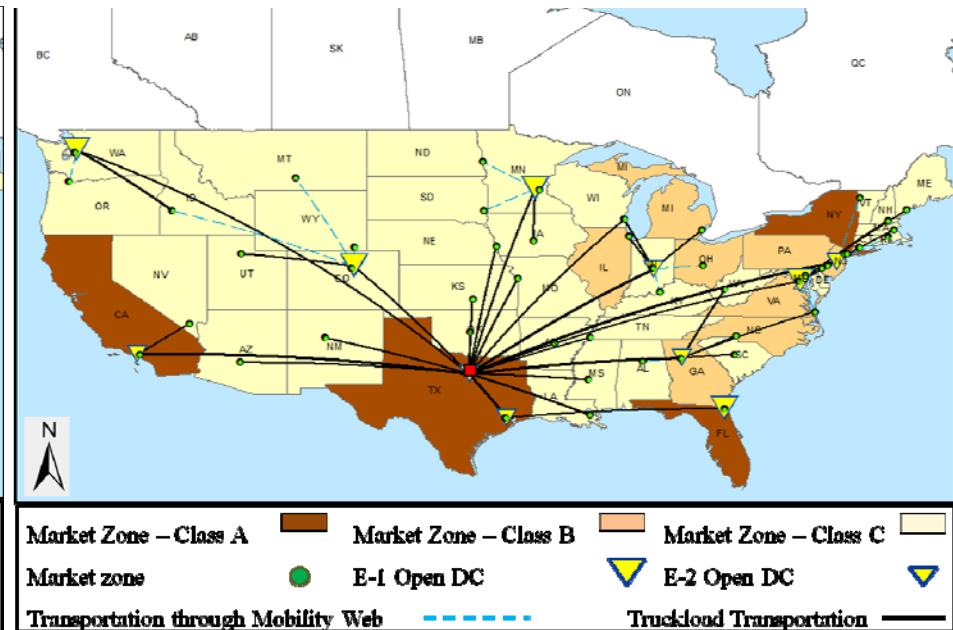
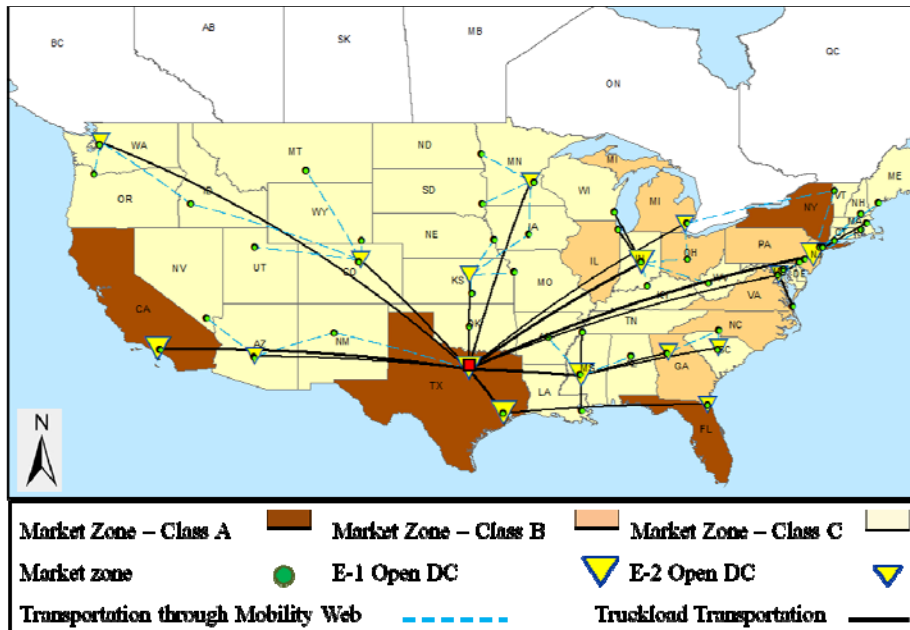
Numerical Experimentation

Distribution Network Topology- Hyperconnected

Hyperconnected distribution networks of the average throughput business (155000 Pallets/Year)

Top service level

Basic service level

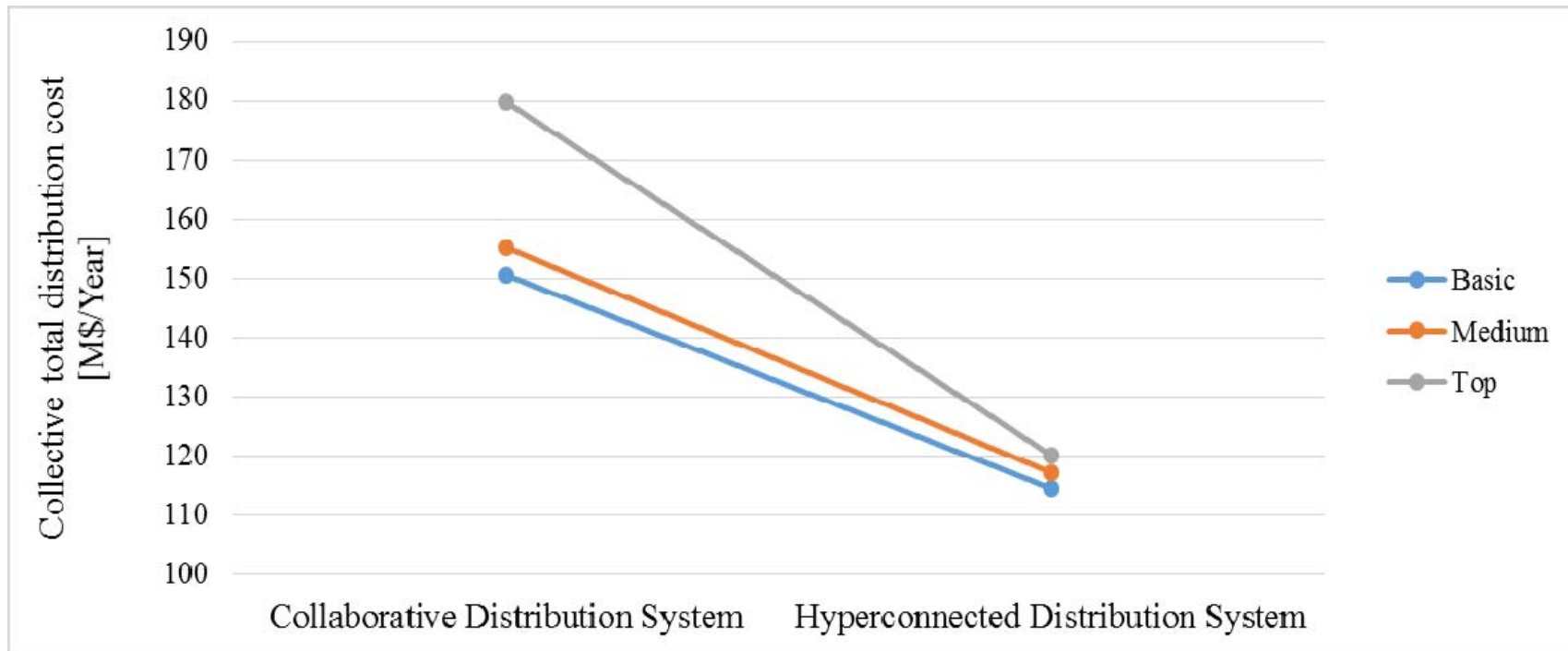


Service Level	Total Distribution Cost [M\$/Year]	Number of DCs (e1, e2)	TL/MTL %-MW%
Top	43	16 (6,10)	60% - 40%
Basic	42.3	14 (5,9)	66% - 34%



Numerical Experimentation

Collective economic performance gain



Collective economic performance evaluation by distribution system and response time policy



Conclusion with Case 1

We modeled the **economic activities** and optimized the distribution webs of **three sampled businesses** adopting alternatively **four** distribution systems from **fully dedicated** to **fully hyperconnected** distribution systems offering any of **three response time policies**.

Our results revealed:

1. The **gain dominance** of Hyperconnected systems over the dedicated systems
2. Providing **faster response time** less expensive with hyperconnected distribution (**2% to 6%** with fully hyperconnected system, in contrast with **16% to 19%** with the fully dedicated system).



Conclusion with Case 2

We modeled the **economic activities** and optimized the distribution webs of **six sampled businesses** adopting alternatively the **collaborative** and **hyperconnected** distribution systems offering any of **three response time policies**.

Our results revealed that:

1. Hyperconnected distribution system can reduce the overall distribution costs by **24% to 33%** in comparison to the collaborative distribution system under basic to top service scenario, respectively.
2. Providing **faster response time** to markets could be significantly less expensive with hyperconnected distribution (**3% to 5%** with the hyperconnected system, in contrast with **16% to 20%** with the collaborative system).



Further Results

By exploiting the Hyperconnected Distribution System:

Economic gain in terms of **Total Distribution Cost**

- **Collective: -22 % to -34 %**
 - ✓ Represent **102** to **185** M\$/Year
- **Single-businesses: from -22% to -52%** (High to Low-throughput for Top service level)
 - ✓ Represent **16** to **28** M\$/Year

Collective **energy consumption**

- **-2 % to -12 %** , represent **59** to **447** TJ/ Year

Collective **GHG emission production**

- **-1 % to -13 %** , represent **2** to **41** MKgCO₂.equivalent/year



Open Questions

- More benefits in a multi-product business case and more companies involved ?
- What if exploiting other transportation modes (not only trucks) ?
- The environmental and social aspects of exploiting the hyperconnected distribution should be also analyzed ?
- What kind of companies would see a high benefit to join ?
- What type of contract / flexibility mechanism must rule Open DCs usage ?

Thank you for your attention !