Georgia Tech | Physical Internet Center

Stewart School of Industrial & Systems Engineering

Urban Large-Item Logistics with Hyperconnected Fulfillment and Transportation

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Last Mile Delivery of Large Items in Urban Area

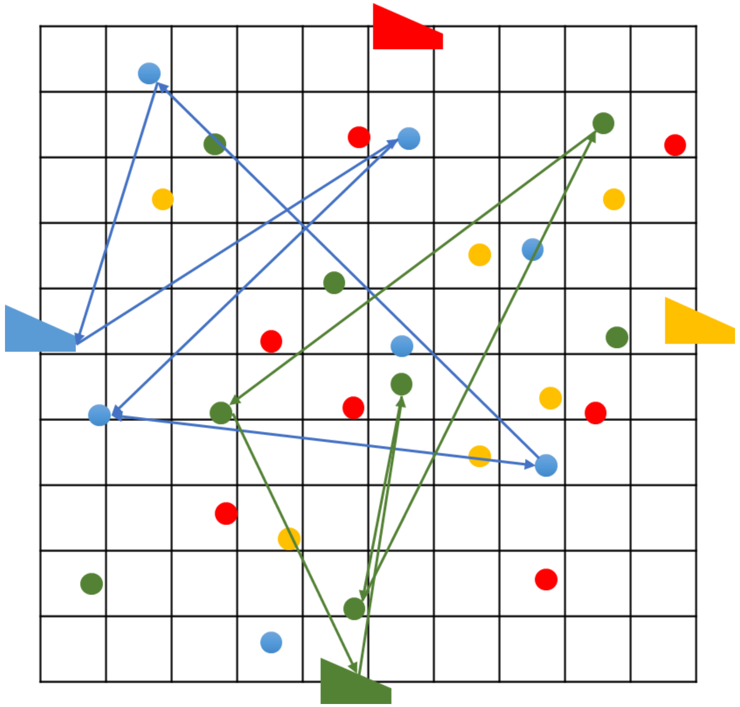
- ❑ Last-mile Delivery
  - ❑ Very last fulfillment, transportation, and delivery to ultimate customer location
  - ❑ The most expensive logistic operations
  - ❑ Directly related to customer experience

- ❑ City Logistics
  - ❑ Growing needs and concerns owing to urbanization and customer expectation on faster, punctual delivery
  - ❑ Considerable social and environmental impact in urban area
e.g. traffic congestion, air pollution
  - ❑ Traditional solution approaches: Routing, Urban Consolidation Center (UCC), Regulations (time, type of vehicles)

- ❑ Furniture and Large Appliances
  - ❑ Large, heavy item dimensions: Limited number of stops in one route
  - ❑ Often requires white-glove services (Delivery and install at delivery location)

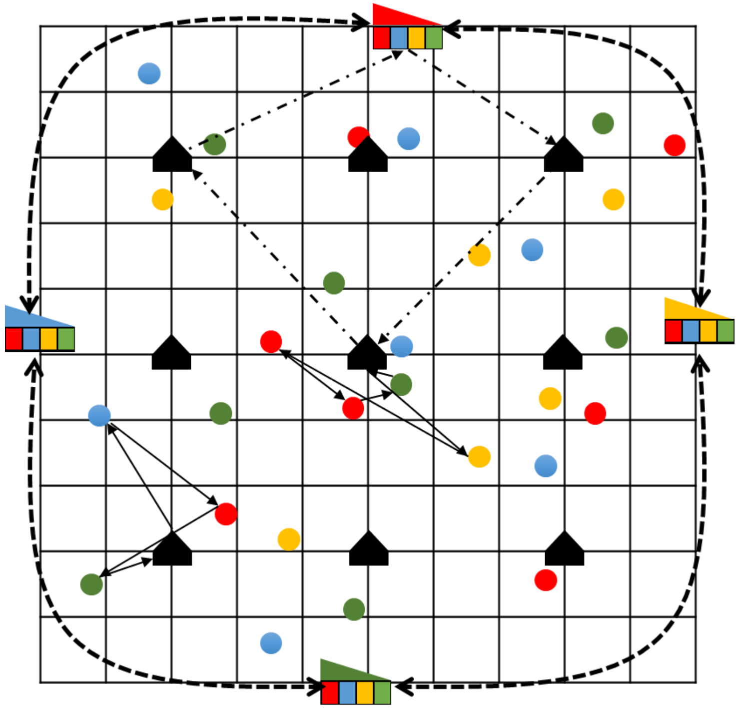
Transformation towards Hyperconnected System

Hyperconnected city logistics system can be a future alternative for efficient, environmentally friendly city logistics system capable of meeting evolving customer needs



Dedicated

Dedicated Fulfillment & Transportation

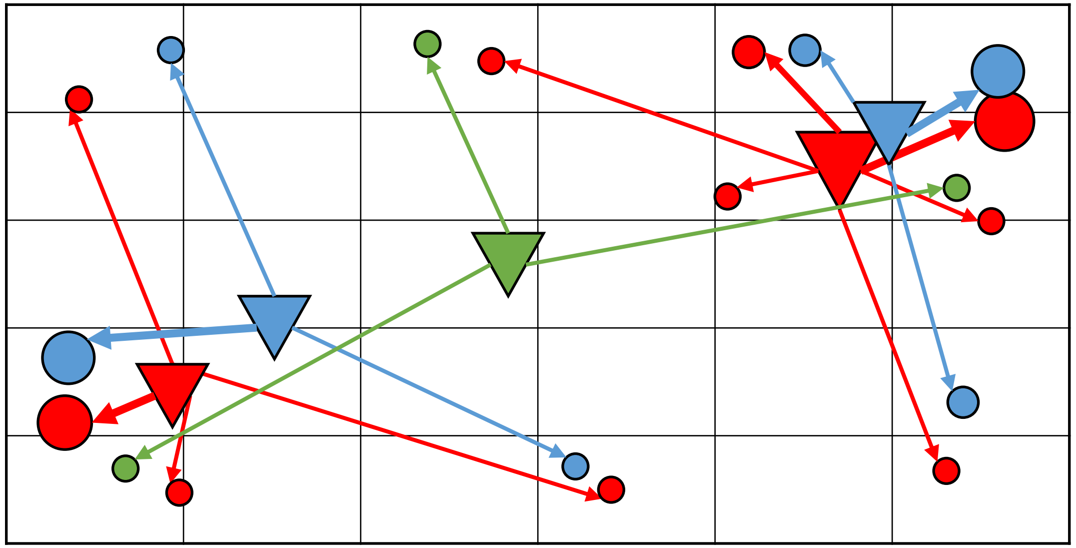


Hyperconnected

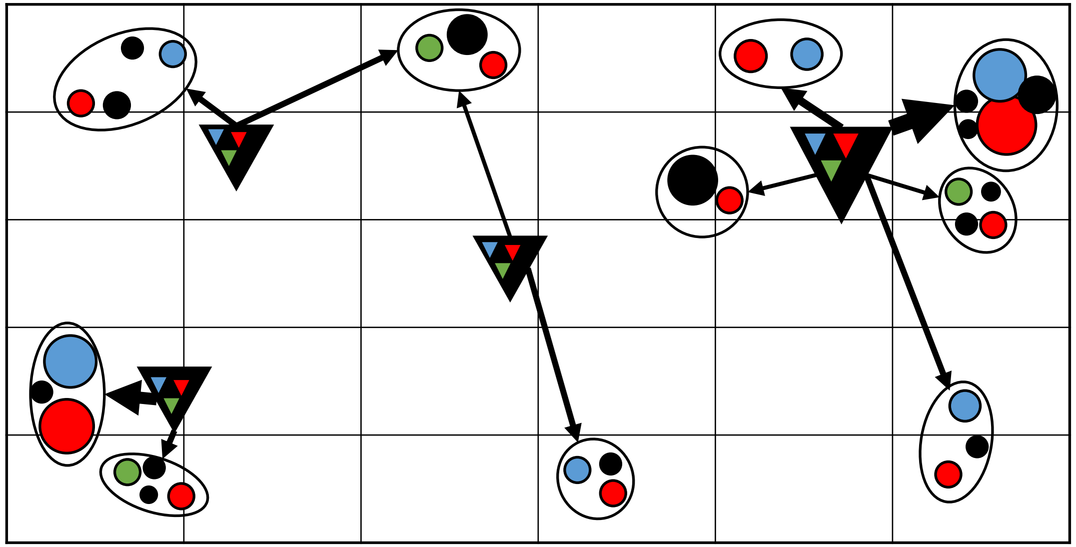
Openly-shared Fulfillment & Transportation

Hyperconnected Fulfillment

Fulfillment with increased capability through unrestricted access to and dynamic inventory deployment over an open network of fulfillment facilities on demand



Dedicated Fulfillment



Hyperconnected Fulfillment

Dedicated fulfillment center (FC) | Openly-shared FC | Demand location | Physical flow

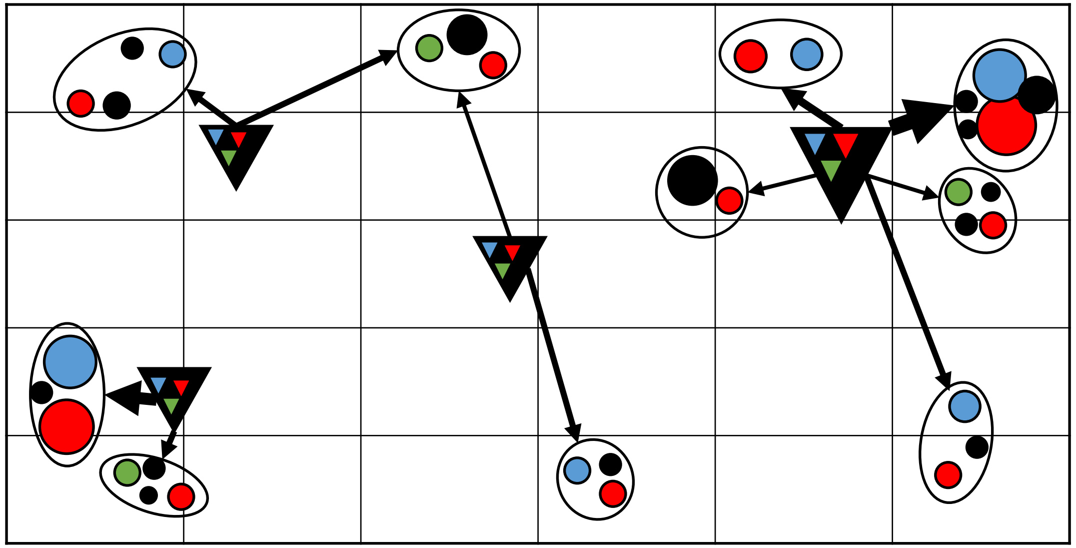
Hyperconnected Fulfillment

- ❑Dedicated Fulfillment
  - ❑Network is optimized for each player
  - ❑Not a Globally Optimal Network

- ❑Hyperconnected Fulfillment

  Network Efficiency
  - ❑Increase proximity to demand locations
  - ❑Consolidate shipments from a fulfillment center (FC) to nearby demand locations
  - ❑Re-optimization: pooled demand can justify a new facility in an under-served area

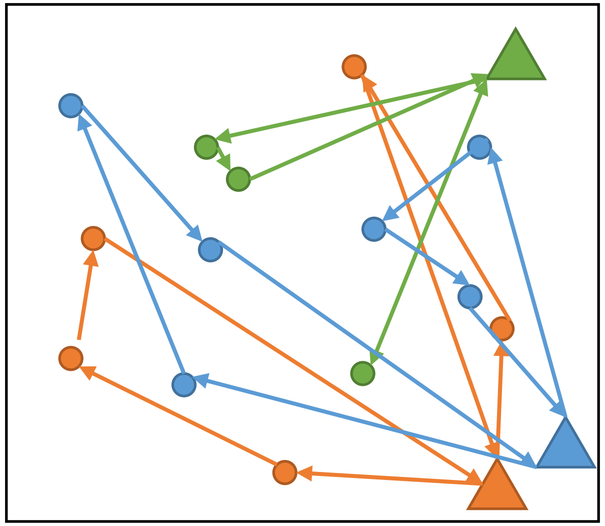
  Facility Efficiency
  - ❑Improve capacity utilization of the FCs



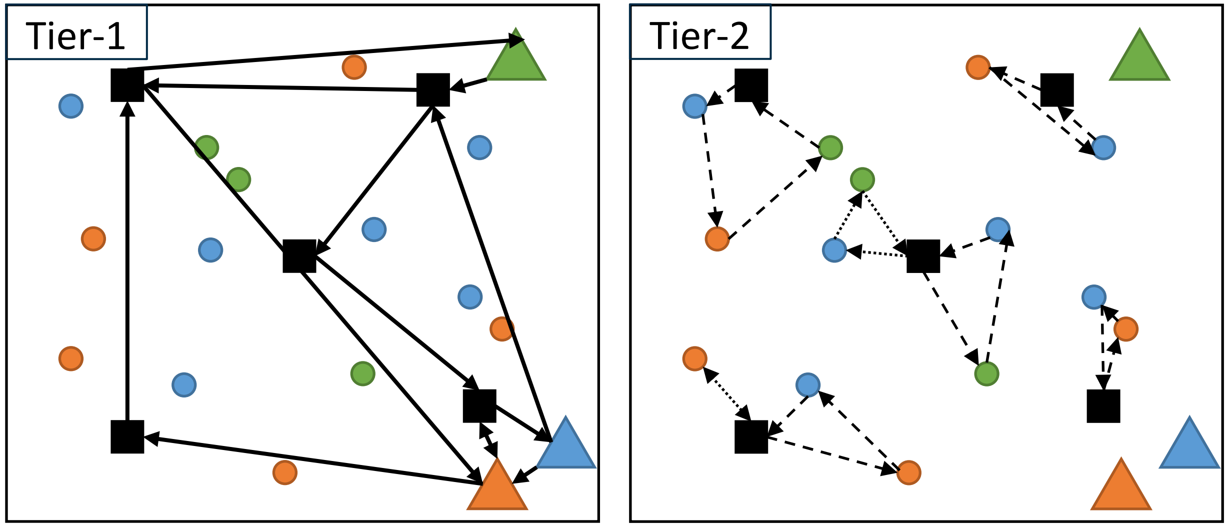
Hyperconnected Fulfillment

Hyperconnected Transportation (Last-mile)

Multi-player routing/shipping
modularized by region and by layer
through utilization of a network of various types of PI hubs
enabling dynamic and broad range of flow consolidation



Last-mile Dedicated Transportation



Last-mile Hyperconnected Transportation (2-tier)[1]

Fulfillment center PI-hub Demand location Dedicated route Tier1 route Tier2 route with type 1 and 2

Hyperconnected Transportation (Last-mile)

- ❑Enable dynamic consolidation among anonymous players at PI hubs
  - ❑Increase fillrate and decrease empty miles
  - ❑Increase shipping frequency without efficiency trade-off

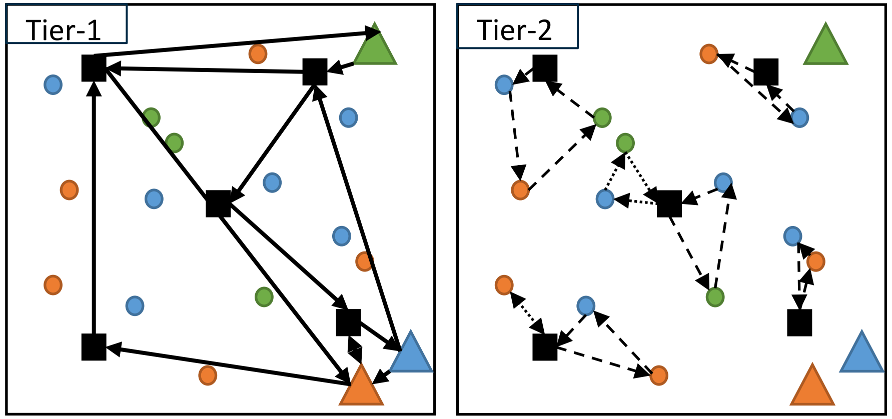
- ❑Enable specialized route through modularization

Physical modularization

- ❑Divide a long route into multiple short routes
- ❑Flexible routing and dynamic consolidation
- ❑Dedicate driver in a limited area
- ❑Specialize to a limited area such as historical city center

Functional modularization

- ❑Divide a route into multiple routes in hierarchy
- ❑Obtain flexibility with respect to transportation mode, time, driver specialty etc.



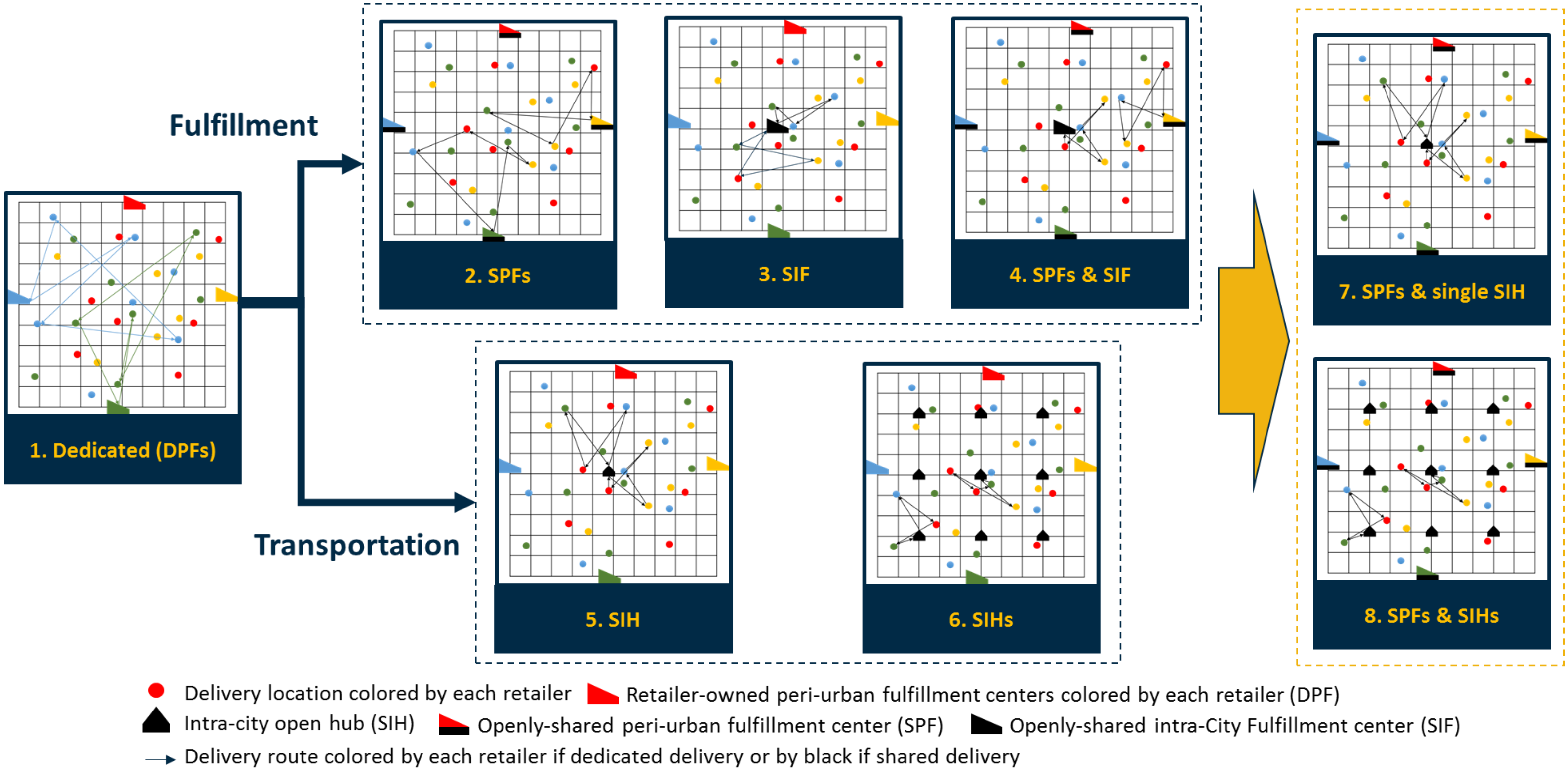
Last-mile Hyperconnected Transportation (2-tier)

Scenario Design

Represent gradual transformation from dedicated to hyperconnected along each thread of fulfillment and delivery

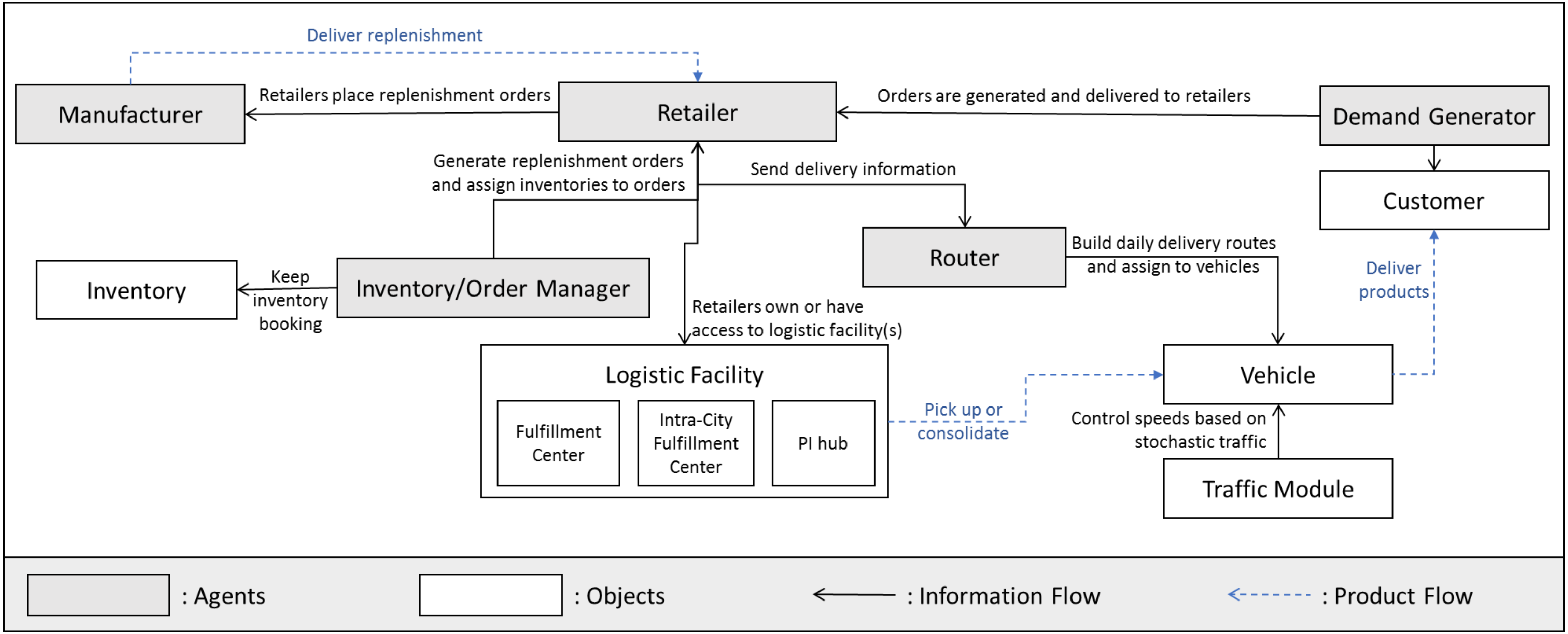
Scenario ID	Scenario Type		Operation Type			
	Fulfillment	Transportation	Peri-urban Fulfillment Center (PF)	Intra-city Fulfillment Center (IF)	Shared Intra-city Hub (SIH)	Delivery
1	Dedicated	Dedicated	Dedicated	-	-	Dedicated
2	Hyperconnected	Openly-shared	Openly-shared	-	-	Openly-shared
3			Dedicated	Openly-shared	-	Openly-shared from SIF
4			Openly-shared	Openly-shared	-	Openly-shared
5	Dedicated	Hyperconnected	Dedicated	-	Single	Hyperconnected
6			Dedicated	-	Web	Hyperconnected
7	Hyperconnected	Hyperconnected	Openly-shared	-	Single	Hyperconnected
8			Openly-shared	-	Web	Hyperconnected

Scenario Design



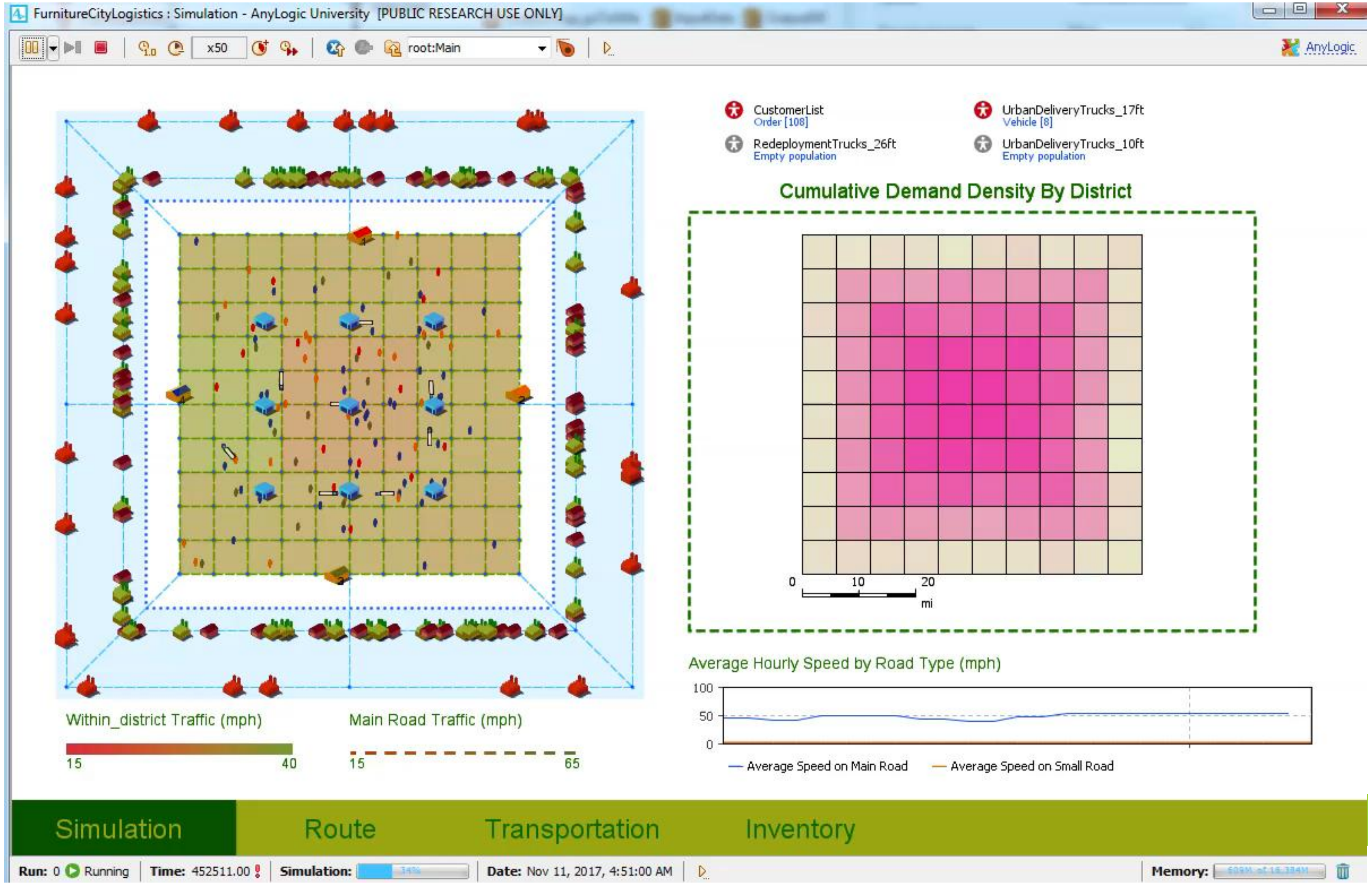
Agent-based Simulation Testbed

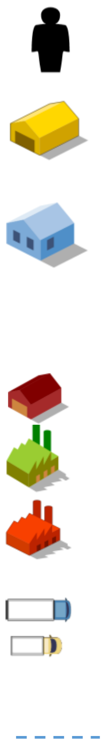
Define scope of simulation, key decision makers, and key operations



Agent-based Simulation Testbed

Each scenario runs for 2.5 years where first 0.5 year is warm-up period





Customer

Peri-urban fulfillment center (FC)

Intra-city fulfillment center (iCFC)

Manufacturer's DC/plant

-Onshore/MTS

-Onshore/MTO

-Offshore/MTO

Last-mile delivery vehicle (17ft (upper) and 10ft (lower))

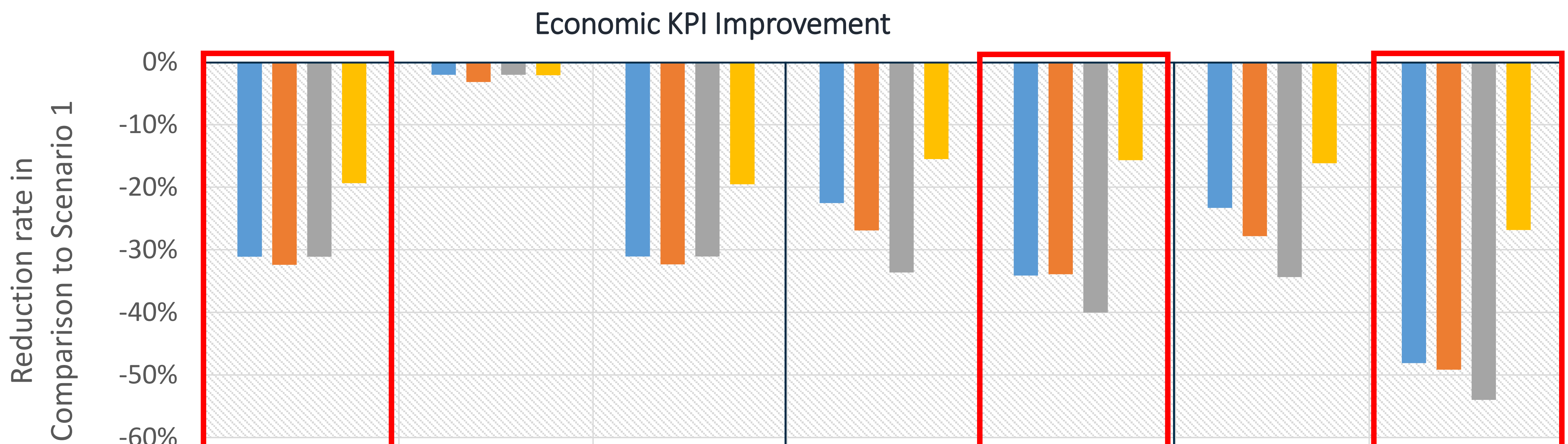
Main road network

Key Performance Indices (KPIs)

- Key performance indices (KPIs) need to cover economical, environmental, and social efficiency and sustainability

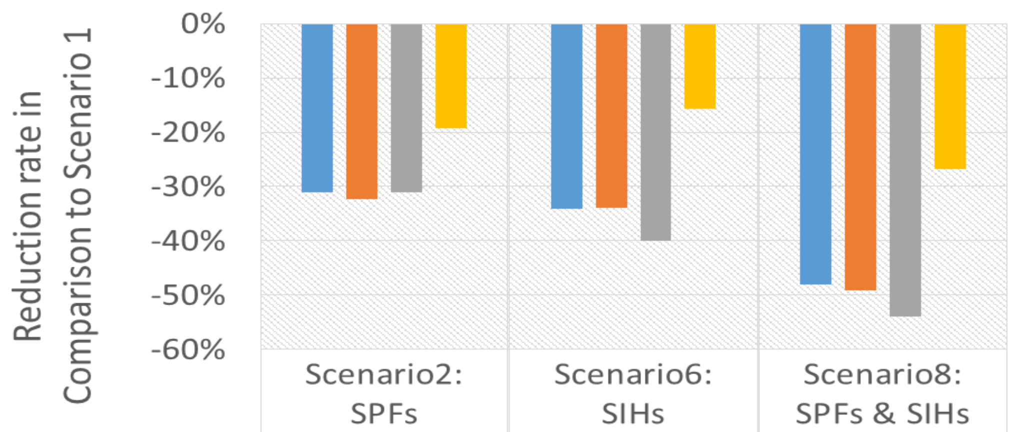
- Economic impacts
  - *Total induced cost (fuel, labor, equipment …)*
  - Daily travel miles
  - Daily labor hours
  - Fuel consumptions
- Service level capability
  - Delays with respect to time window
- Environmental impacts
  - Greenhouse gas emission (CO_2, SO_2, NO_2)
  - Emission of fine particles ($PM_{2.5}$)

Experimental Results: Economic Impact

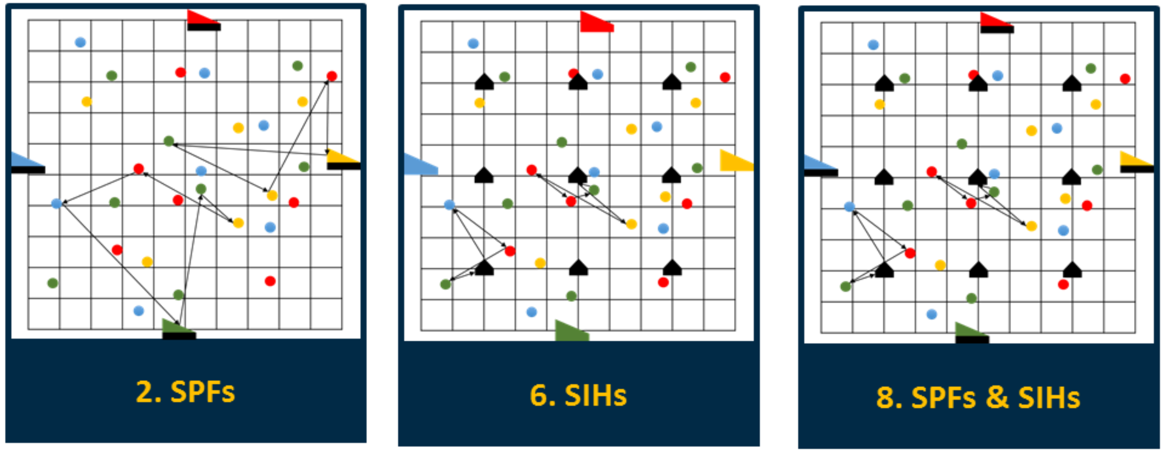


	Scenario2: SPFs	Scenario3: SIF	Scenario4: SPFs & SIF	Scenario5: SIH	Scenario6: SIHs	Scenario7: SPFs & SIH	Scenario8: SPFs & SIHs
Travel Mile	-31%	-2%	-31%	-23%	-34%	-23%	-48%
Driving Hour	-32%	-3%	-32%	-27%	-34%	-28%	-49%
Fuel Consumption	-31%	-2%	-31%	-34%	-40%	-34%	-54%
Labor Hour	-19%	-2%	-20%	-15%	-16%	-16%	-27%
	Hyperconnected Fulfillment			Hyperconnected Transportation		H. Fulfillment & Transportation	

Experimental Results: Economic Impact

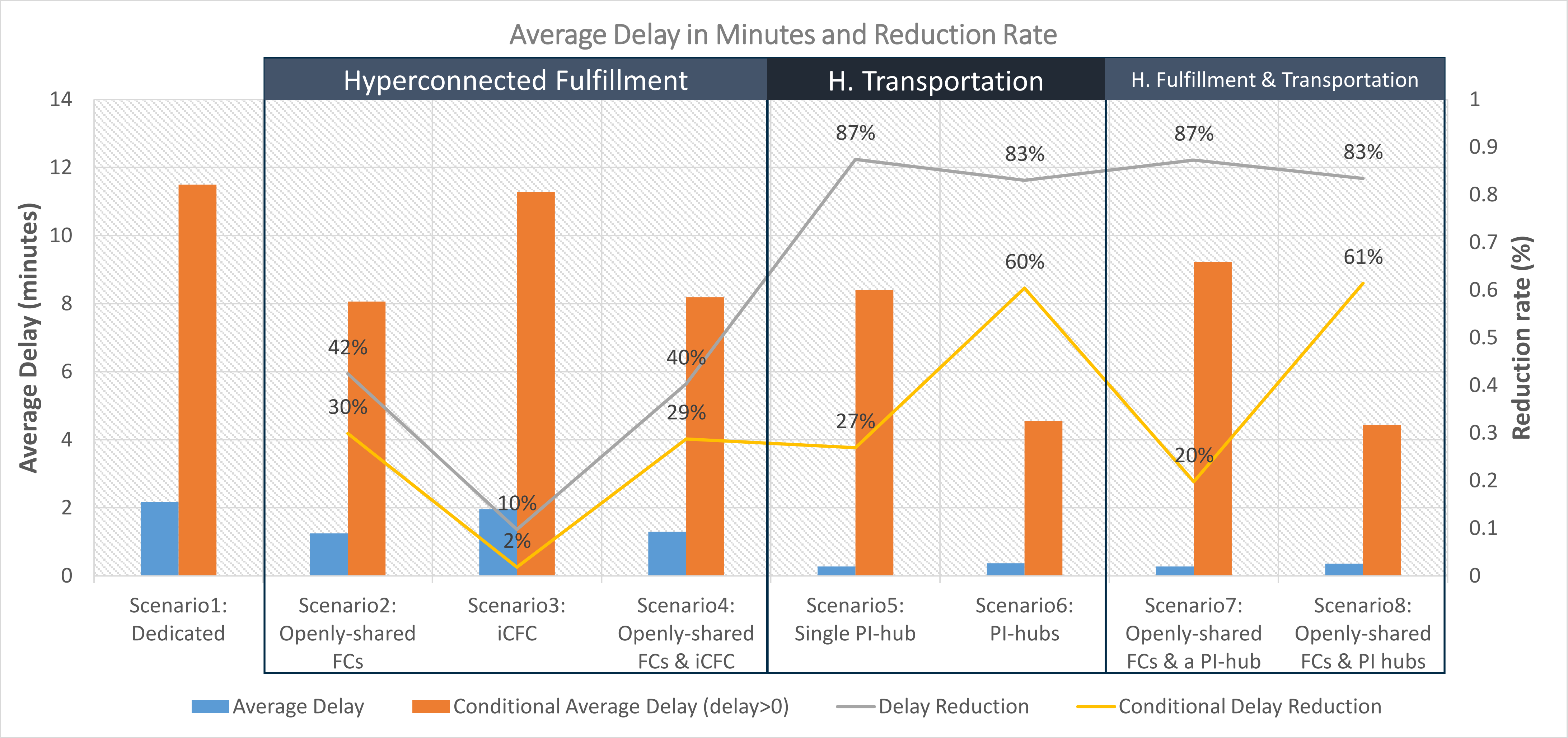


	Scenario2: SPFs	Scenario6: SIHs	Scenario8: SPFs & SIHs
Travel Mile	-31%	-34%	-48%
Driving Hour	-32%	-34%	-49%
Fuel Consumption	-31%	-40%	-54%
Labor Hour	-19%	-16%	-27%



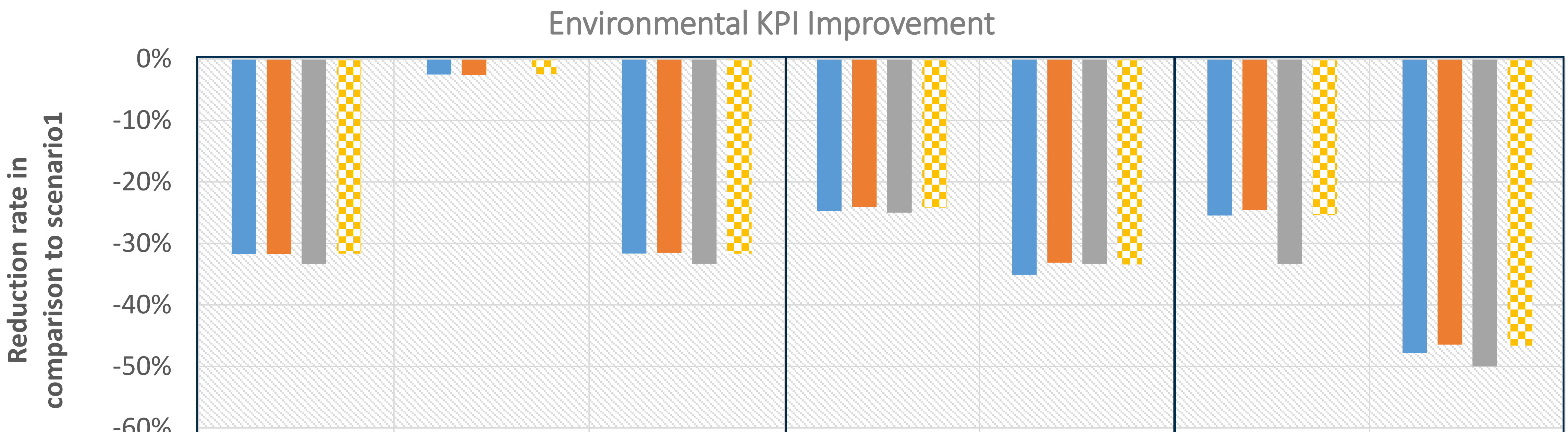
- All the economical KPIs are improved significantly with hyperconnected system (~50% reduction in travel miles/fuel consumptions)
- Hyperconnected fulfillment or transportation solely can achieve about 60% of improvement of hyperconnected fulfillment AND transportation system
- Reduction in labor hour is limited due to fixed labor hour for delivery and installment
- Reduction in fuel consumption exceeds the reduction in travel mile with hyperconnected delivery due to the ability of utilizing smaller and more environmentally friendly vehicles in tier 2

Experimental Results: Service-level Capability



- Both delay time and frequency can be reduced significantly especially with hyperconnected transportation

Experimental Results: Environmental Impact



	Scenario2: SPFs	Scenario3: SIF	Scenario4: SPFs & SIF	Scenario5: SIH	Scenario6: SIHs	Scenario7: SPFs & SIH	Scenario8: SPFs & SIHs
CO2 Emission	-32%	-3%	-32%	-25%	-35%	-25%	-48%
NO2 Emission	-32%	-3%	-32%	-24%	-33%	-25%	-46%
SO2 Emission	-33%	0%	-33%	-25%	-33%	-33%	-50%
PM2.5 Emission	-32%	-2%	-32%	-24%	-33%	-25%	-47%
	Hyperconnected Fulfillment			H. Transportation		H. Fulfillment & Transportation	

- Similar to economic KPIs, greenhouse/toxic gas and fine particle emission rates are reduced significantly with hyperconnected fulfillment and/or transportation

Conclusion

- ✓Just openly-sharing existing peri-urban FCs can significantly improve last-mile operations especially when they are widely spread
- ✓It is not necessary to build a fulfillment center in the expensive city area to improve last-mile logistics;
  However, single intra-city PI hub can bring significant improvement
- ✓Web of PI hubs can improve last-mile logistics operated with openly-shared FCs;
  Use of smaller delivery vehicle for last-mile can further improve congestion and reduce negative environmental impacts
- ✓Demonstrate the capability and effectiveness of simulation-based scenario analysis for research in Physical Internet

Future Study (ongoing)

- Study the scenarios in a variety of contexts
  e.g. city topologies, demand patterns, facility locations

- Investigate the potential of further improvement by separating and synchronizing delivery operation and white-glove services

Thank you ☺

Questions, Comments, and Discussions!

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