Georgia Tech Physical Internet Center
Supply Chain & Logistics Institute

OPTIMIZING HIGH-VALUE PRODUCT AVAILABILITY IN HYPERCONNECTED RETAIL NETWORKS

PRESENTER: JINYONG YIM

DR. SHAHAB DERHAMI

PROF. DR. BENOIT MONTREUIL

PHYSICAL INTERNET CENTER
SCHOOL OF INDUSTRIAL & SYSTEMS ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

CREATING THE NEXT®

7-10-2019

Product Availability Ratio (PAR)

A New Key Performance Indicator
Described Hereafter for Hyperconnected Retail Networks of High-Value Products

Product Availability Ratio: a Key Performance Indicator for Retailing

Assessing the readiness of a retail center of high-value products to satisfy uncertain demand

[Components of Product Availability Ratio (PAR) Calculation for a Dealer]

For each potential client, taking into consideration his desired product, his pickup time flexibility, and his openness to substitution

What is the best combination of products and delivery time that can be offered to the client exploiting all potential sources?

Why we need PAR rather than counting only on inventory profile?

1. Some customers are willing to wait for their desired products
2. Some customers are willing to substitute product if their desired product is not available
3. There exists on-demand transshipment capability

How Physical Internet facilitates fast and economic transshipments and product deployment, enhancing PAR performance capability?

1. Exploit hyperconnected multi-party networks of retail centers, depots, distribution centers, production facilities, shipyards, etc.
2. Deploy live open monitoring of all product storage places
3. Encapsulate products in smart green modular containers

[Reference] Montreuil B., Derhami S., Bau G. (2019): Beyond inventory position: assessing product availability across a network of interconnected customer-centric retailers. *(Under review in European Journal of Operational Research)*

In-Store Availability of Product Demanded by Client Stan at Retailer BigToys

Stan demands this vehicle

Different Color
Different Engine

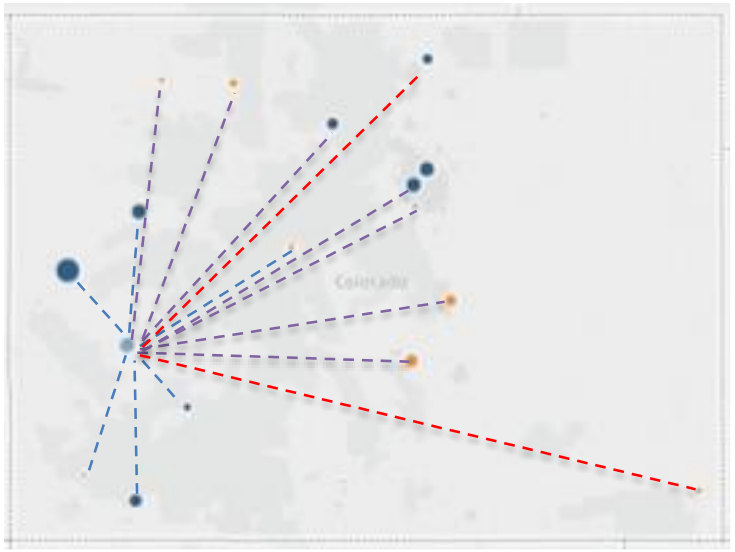
BigToys can best offer this vehicle from its inventory

It has a substitution fitness of 60% given the client's demand

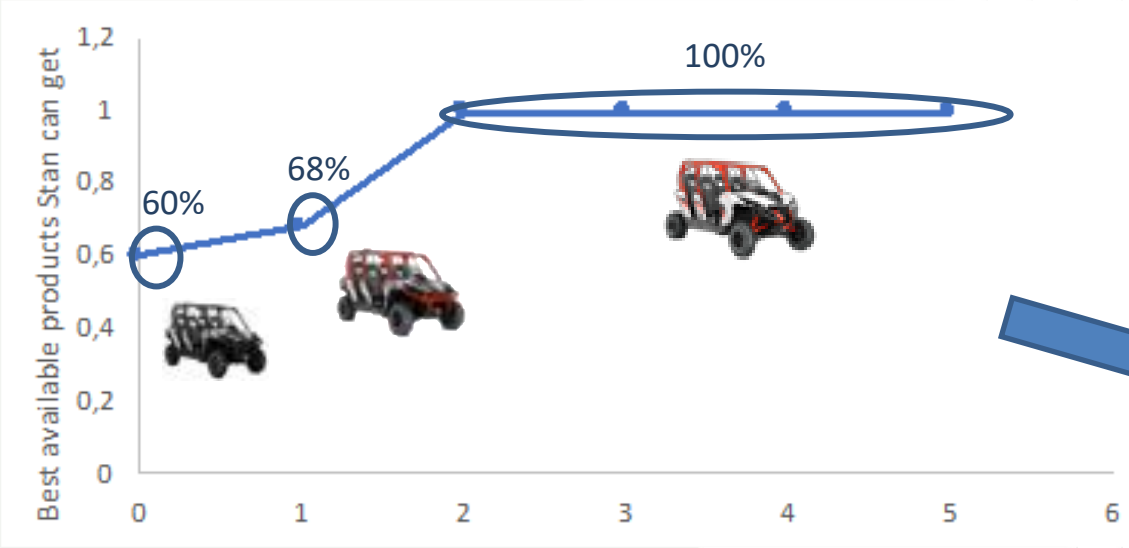
The probability of acceptance by Stan is estimated to be 23%

Network Availability of Product Demanded by Client Stan at Retailer BigToys

An Example of Hyperconnected Network Exchanges

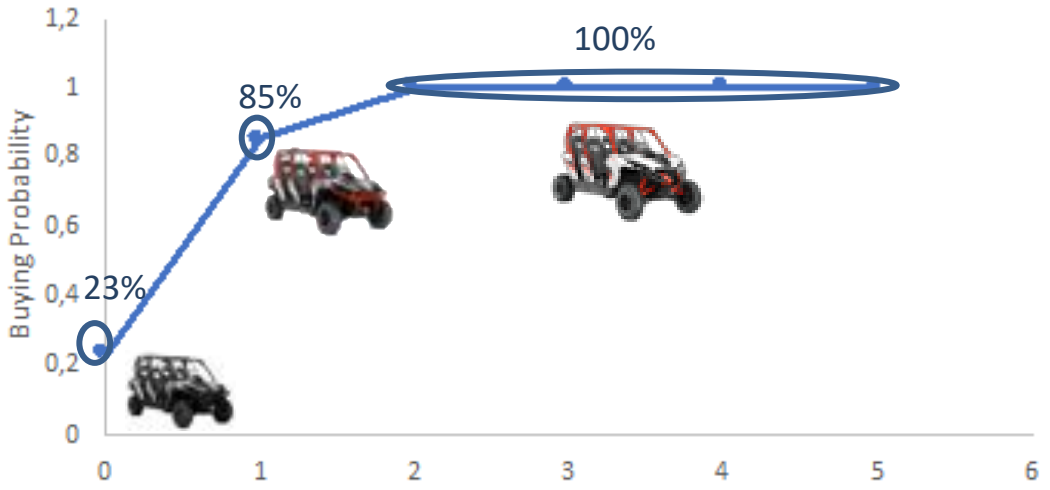


Best Available Fitness Given Stan's desired model



Willingness to wait

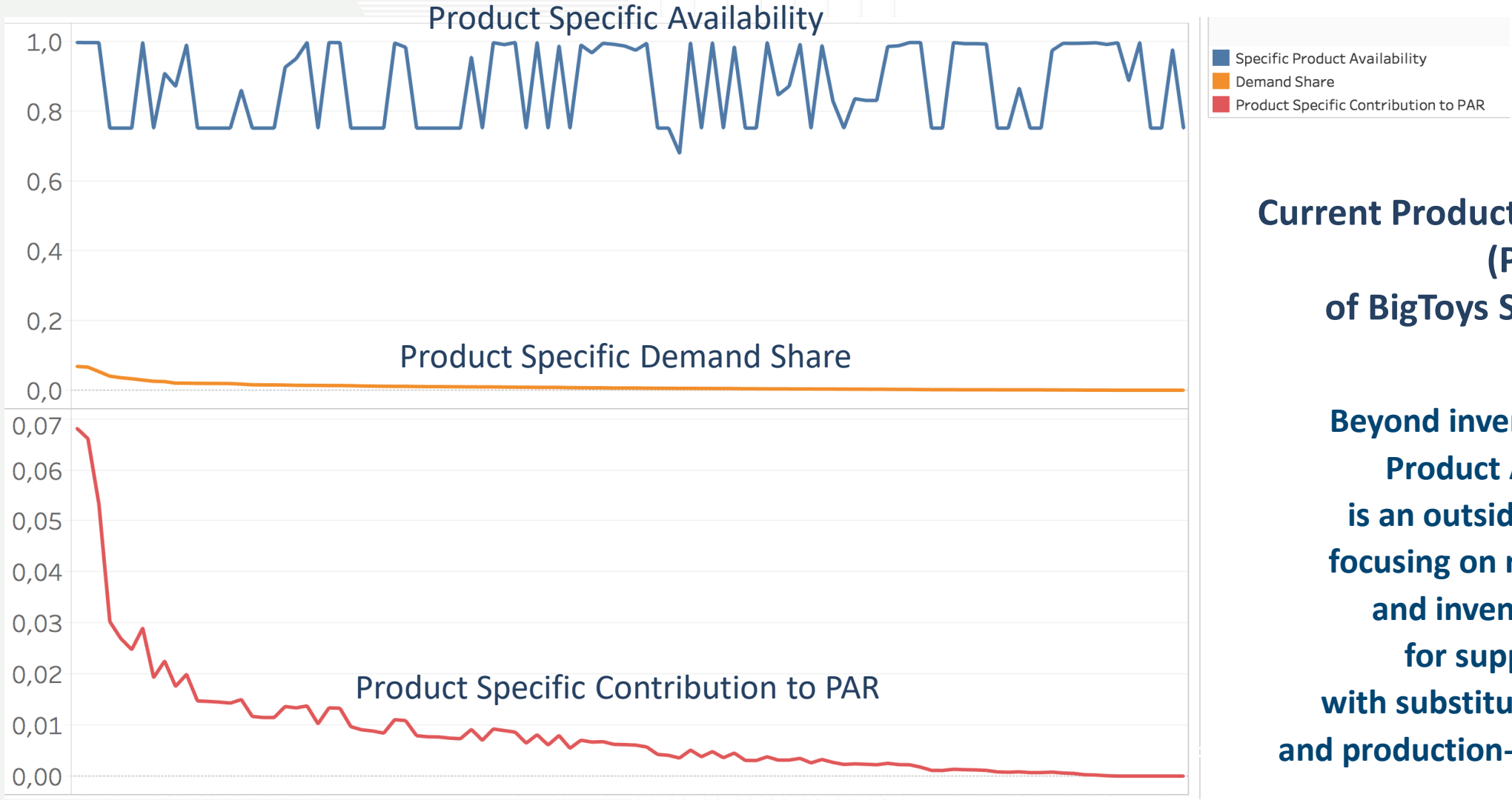
Stan's buying probability of offered model



Willingness to wait

Exploiting BigToys Store and Other Sources Within the Demand Response Network

Current Product Availability Ratio of BigToys Store



Products (50) in decreasing order of estimated demand share at the specific dealer

Current Product Availability Ratio (PAR) of BigToys Store is 87.5%

Beyond inventory quantity, Product Availability is an outside-in indicator focusing on responsiveness and inventory quality for supply chains with substitution, exchange, and production-to-order potential

Case-Study-Based
Physical Internet-Driven PAR Optimization Experiment

Case Study: A Leading Manufacturer of Recreational Vehicles

Product Examples

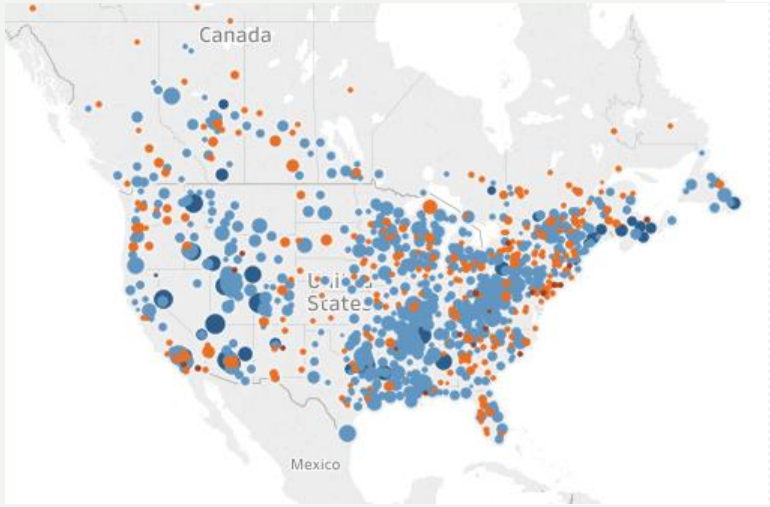
On-road Vehicle

Off-road Vehicle

Watercraft

Snowmobile

Several hundreds of retail centers in North America



Unsustainability Symptoms of Retail Centers

1. Products mostly sit idle, stored where unneeded, yet so often unavailable fast where needed
2. So many products are never sold, never used
3. Each retailer decides what to order independently and locally

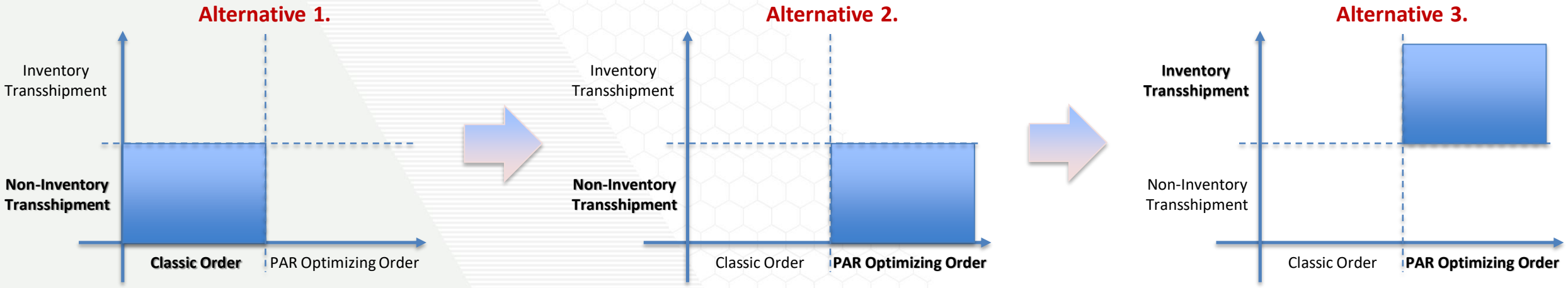
PAR Optimization

Physical Internet Vision

1. Aim toward universal hyperconnectivity in transportation, distribution, production & supply
2. Minimize physical moves and storages by digitally transmitting knowledge and real-time information
3. Deploy live open monitoring of all storage places such as other nearby retail centers, distribution centers, and production facilities

[Reference] Montreuil B. (2011): Toward a Physical Internet: meeting the global logistics sustainability grand challenge. *Logistics Research*, 3, 71-87.

Experimental Design for Investigating PAR Optimization



Three Alternatives for the Experiment

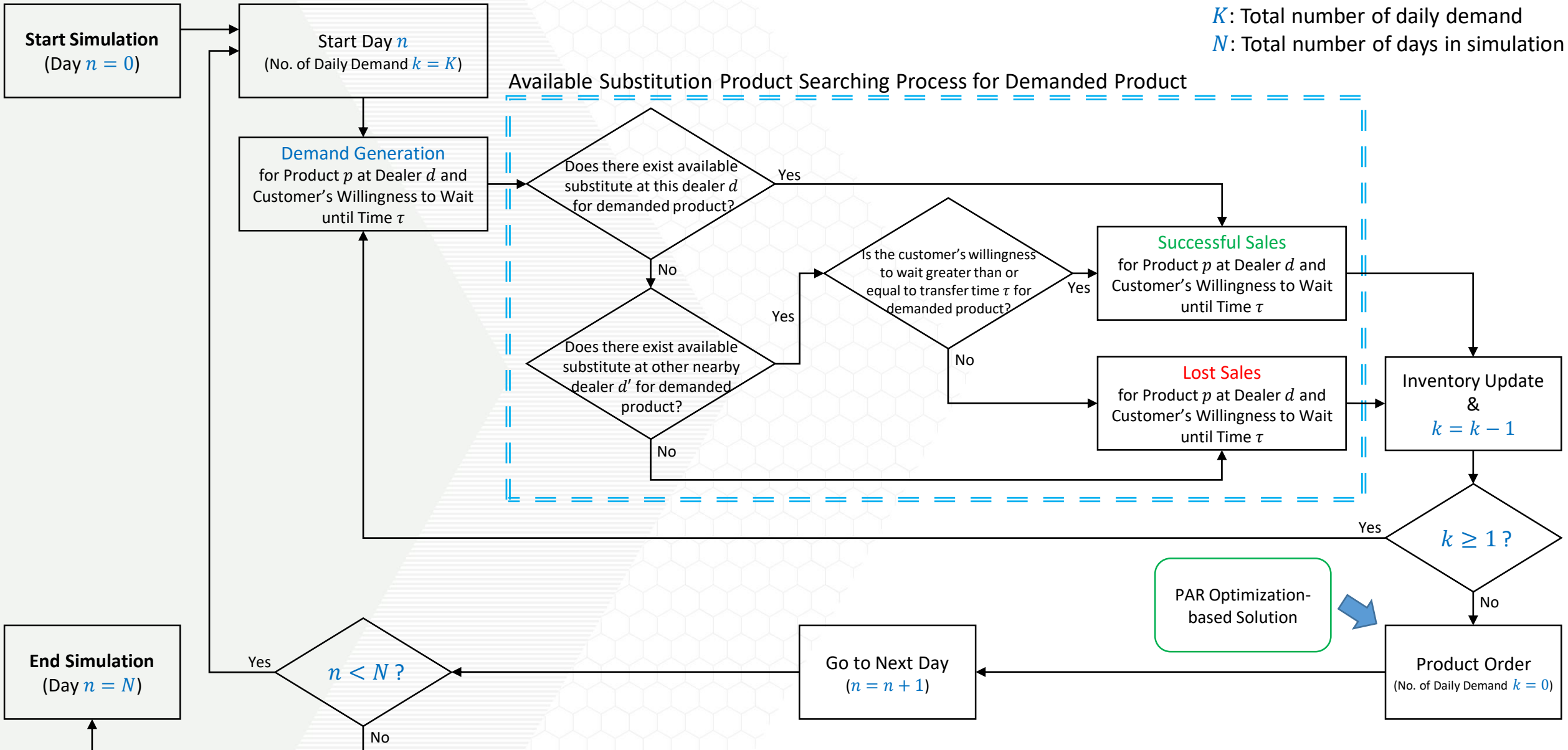
1. Actual dealer order of the case company during the simulation period
2. Single dealer focused PAR optimizing order
3. Hyperconnected network-based PAR optimizing order

Experimental Design

- 17 dealerships in one state and 102 products of a certain category of vehicles
- 6 business day for the simulation period in a given week in 2018
- 4 customers daily as an overall regional demand, each demanding a specific product

Order Policy	Alternative 1	Alternative 2	Alternative 3	Physical Internet - Related Facets
Product Substitution		✓	✓	○ Better utilize storage space and increase inventory turnover by selecting the best fitting combination of products
Inventory Transshipment			✓	○ Exploit hyperconnected networks among multiple dealers ○ Deploy live open monitoring of all other nearby dealers
Customers' Willingness to Wait for Their Desired Products			✓	

Simulation Model to Generate Hyperconnected Network-Based Scenarios



Product Availability Optimization Model

[Goal]
Maximize Product Availability Ratio (PAR) for Dealers in the Hyperconnected Network by deciding which Product to order at which Dealer given the Share of Customers' Willingness to Wait for Their Desired Products

[Indices]
d, d' : Dealer
p, p' : Product
τ : Time

[Variables]
$A_{pd\tau}$: Availability of product p at dealer d in time τ
$F_{pdp'd'}$: 1 if product p' from dealer d' is the offered substitution for product p to dealer d, 0 otherwise
I_{pd} : 1 if product p is in inventory at dealer d, 0 otherwise
O_{pd} : 1 if product p is ordered by dealer d, 0 otherwise

[Parameters]
$a_{pp'}$: Product substitution availability of product p' for product p in time 0, $a_{pp'} \in \{0,1\}\ \forall p, p'$
d_{pd} : Expected demand share $[0,1]$ of dealer d for product p in the network, $(\sum_{pd} d_{pd} = 1)$
i_{pd} : Current inventory of product p at dealer d, $i_{pd} \in \{0,1\}\ \forall p, d$
m_d : Maximum dealer portfolio size for dealer d
$s_{pdp'd'\tau}$: Time-based substitution fitness of product p requested from dealer d until time τ offered by product p' currently in dealer d'
v_t : Share $[0,1]$ of customers' willingness to wait until time $\tau \in \{0,1,2,3\}$, $(\sum_{\tau} v_t = 1)$

[Objective Function]
Maximize PAR $= \sum_{\tau} v_t \sum_{pd} d_{pd} A_{pd\tau}$ (0)

[Constraints]
The total sellable inventory becomes equal to the sum of the order and the current inventory
$I_{pd} = O_{pd} + i_{pd}$ $\forall p, d$ (1)

The portfolio size of each dealer is restricted by the maximum dealer portfolio size
$\sum_p I_{pd} \leq m_d$ $\forall d$ (2)

The distance product substitution is available only if there is no substitutable product at the selected dealer
$F_{pdp'd'} \leq 1 - a_{pp'} I_{p'd}$ $\forall p, d' \neq d, p'$ (3)

The product substitution is available only if the substitution product exists
$F_{pdp'd'} \leq I_{p'd'}$ $\forall p, d, p', d'$ (4)

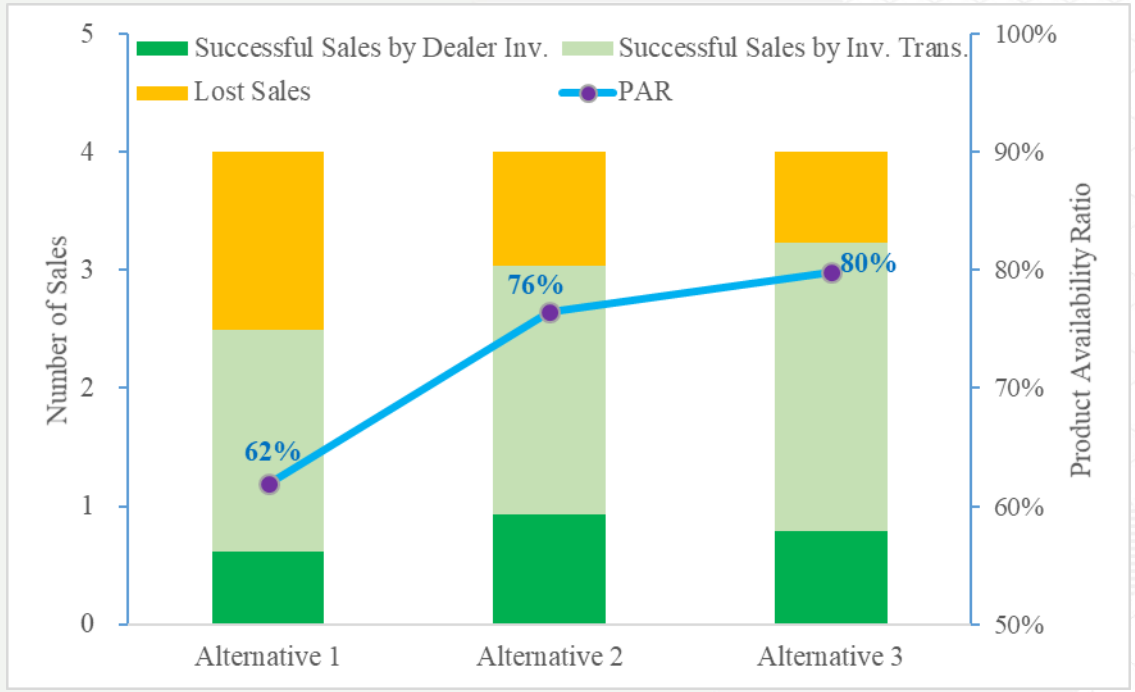
Each product at each dealer can be substituted by only one product from one dealer
$\sum_{p'd'} F_{pdp'd'} \leq 1$ $\forall p, d$ (5)

Product availability constraints
$A_{pd\tau} = \sum_{p'd'} s_{pdp'd'\tau} F_{pdp'd'}$ $\forall p, d, \tau$ (6)

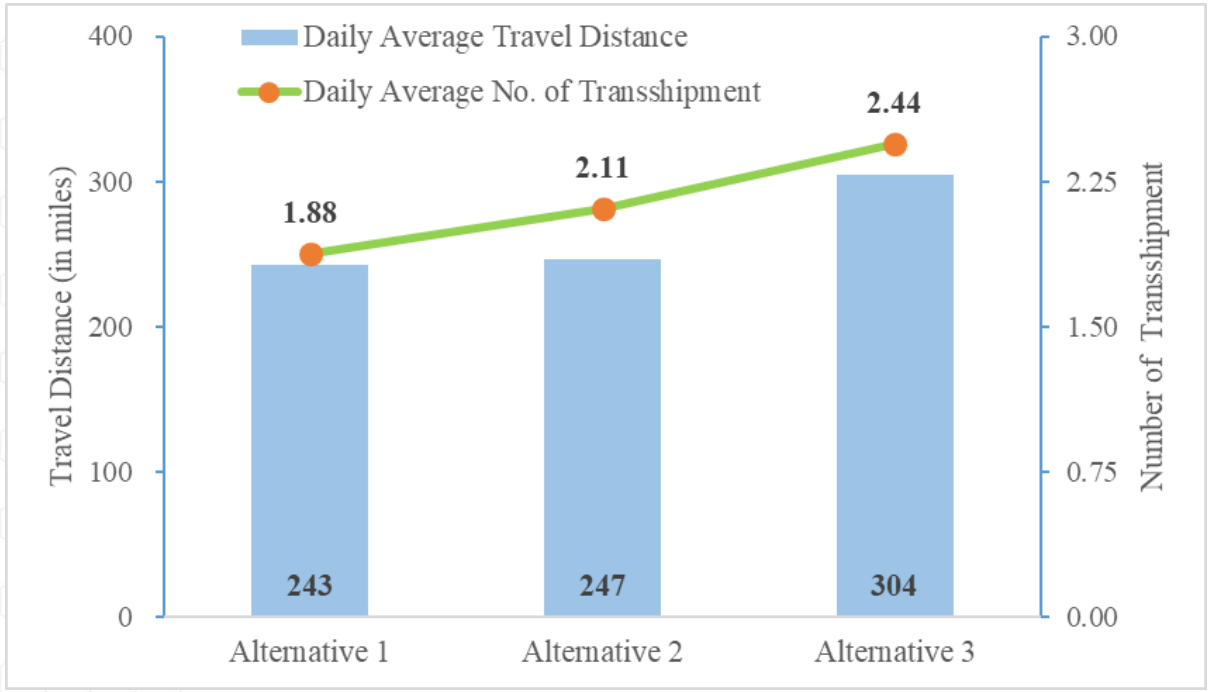
Binary variable constraints
$F_{pdp'd'} \in \{0,1\}$ $\forall p, d, p', d'$ (7)
$I_{pd} \in \{0,1\}$ $\forall p, d$ (8)
$O_{pd} \in \{0,1\}$ $\forall p, d$ (9)

Experimental Results of PAR Optimization

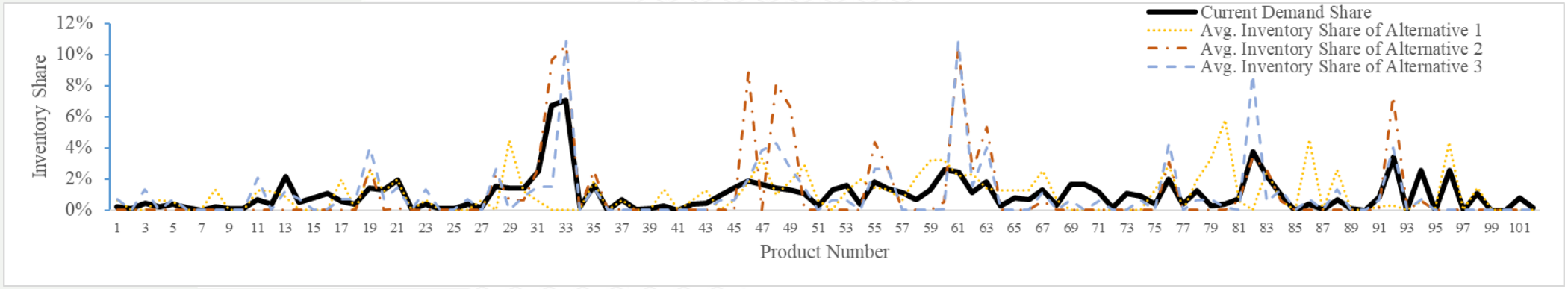
Daily Average Successful Sales, Lost Sales, PAR



Daily Average Number of Transshipment and Corresponding Travel Distance



Daily Average Network Inventory Share



Future Research

1. Further investigate the exploitation of non-dealer external resources in the model such as depots, warehouses and production facilities so as to concurrently maximize the hyperconnected network-based PAR performance and overall sustainability
2. Design and investigate large-scale solution approaches for efficient PAR optimization
3. Investigate deeper the explicit gain in PAR, sales, profitability and sustainability performance enabled by Physical Internet hyperconnectivity
4. Extend the investigation to other high-value products
5. Extend the investigation to lower-value higher-demand products

Questions and comments are most welcome

jinyongyim@gatech.edu

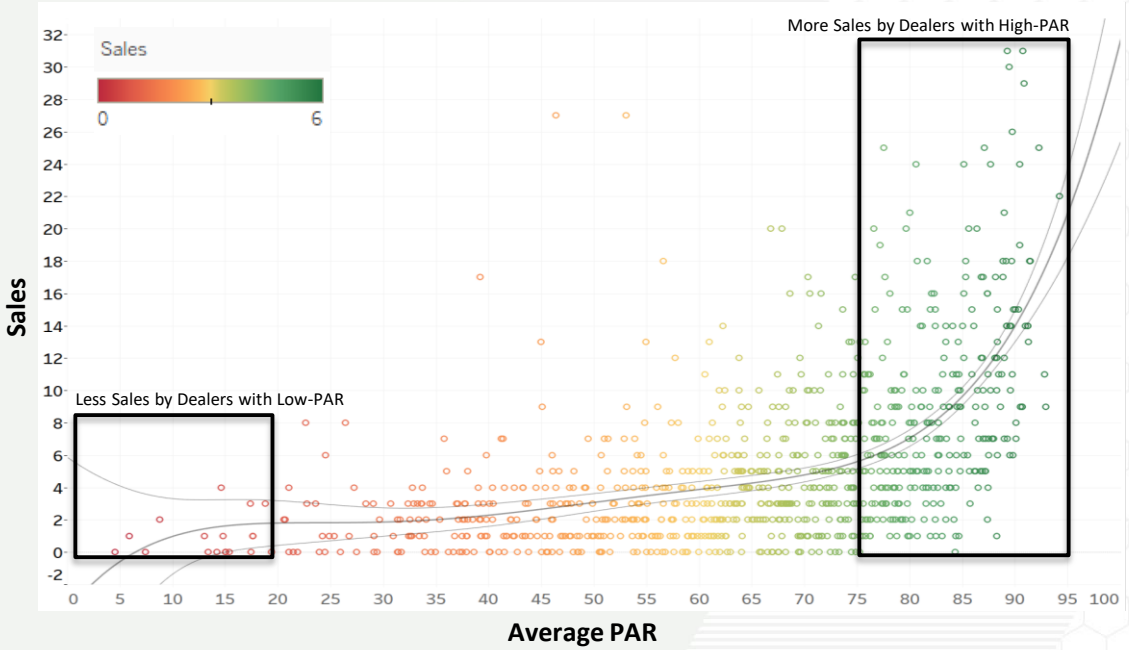
shahab.derhami@isye.gatech.edu

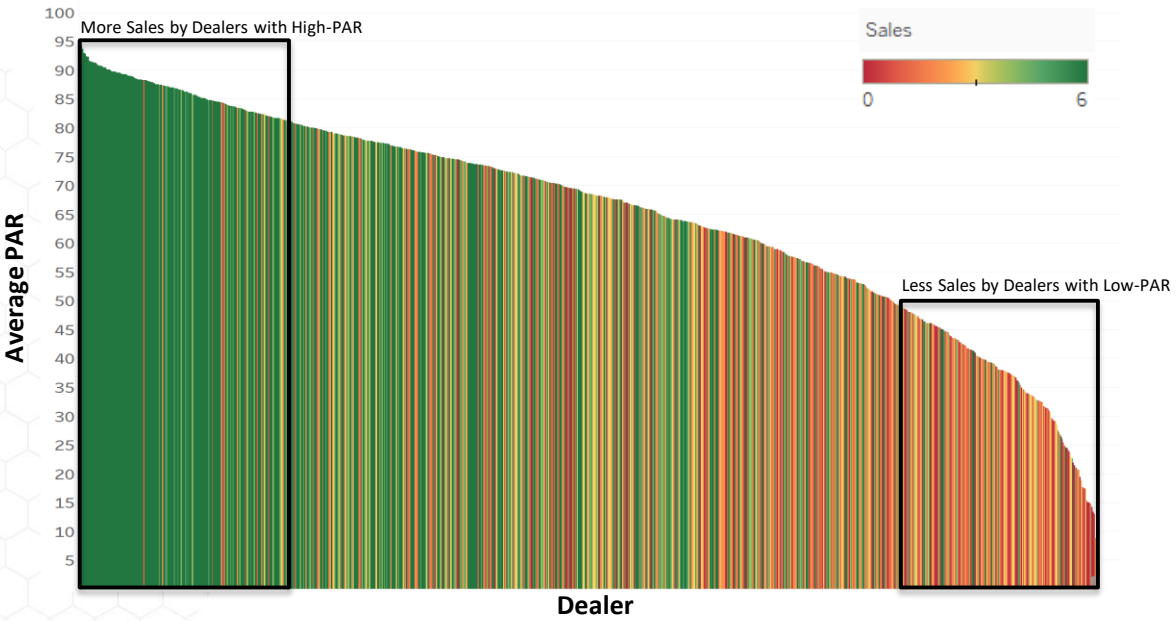
benoit.montreuil@isye.gatech.edu

[Appendix]

Correlation between Product Availability Ratio and Sales

The Correlation between PAR and Dealer Sales





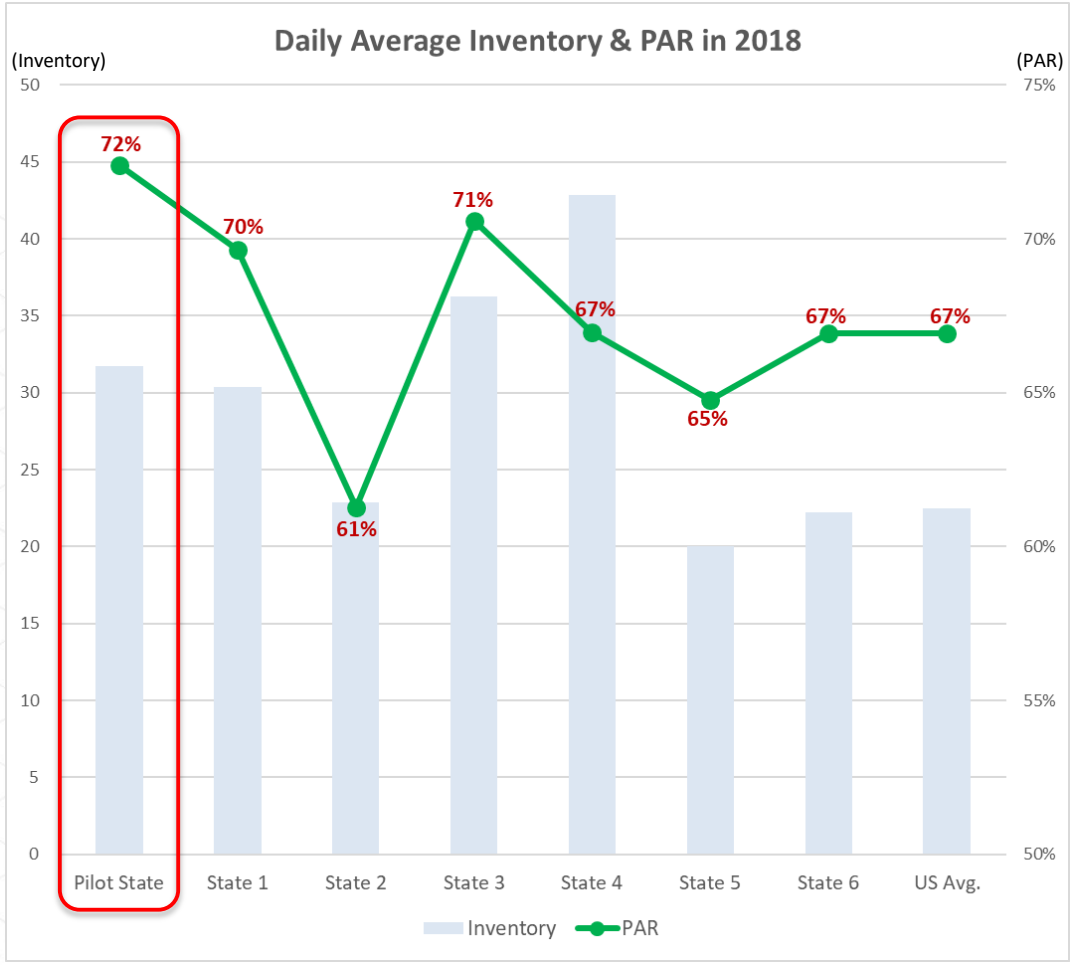
PAR is a value between 0%-100% intrinsic to a dealer at a given time

Achieving a 100% PAR at a dealer today means that whatever an incoming customer is demanding, the dealer is able to satisfy with a perfect fitting product within a perfectly acceptable time window of the customer

100% PAR can only happen when a dealer has all the products in its inventory or if the customer is indifferent to pickup times within a significant time window, allowing the dealer to get all products on time

100% PAR means the dealer cannot possibly miss a sale nor only partially satisfy a customer due to supply chain issues

Industry Case Study Results from Pilot Test for a Selected State



- **The sales growth rate of the pilot state was ranked as one of the highest top 5 in the U.S. in 2018**
- **Compared to similar states in terms of this industry retails, the pilot state's PAR was the highest in 2018**
- **However, the daily average inventory level of the pilot state in 2018 was similar to other states**