Optimizing High-Value Product Availability in Hyperconnected Retail Networks

Jinyong Yim, Shahab Derhami, and Benoit Montreuil
H. Milton Stewart School of Industrial & Systems Engineering, Georgia Institute of Technology, Atlanta, USA
Corresponding author: jinyongyim@gatech.edu

Abstract: *This paper addresses the optimization of dealer replenishment decisions in planning their assortment for high-value substitutable products so as to maximize product availability of dealers in hyperconnected retail networks. To achieve this, we formalize the problem as a discrete optimization model, and provide exploratory empirical results based on a Monte Carlo simulation for a case study of a leading manufacturer of recreational vehicles. Then, we show that the proposed model achieved sales increase by 30% in a given network while keeping the same inventory level as the current business model. Emphasizing availability rather than inventory, we present the contribution of this paper in assortment planning, inventory transshipment, customers' substitution behavior, and product availability. We conclude the paper with a call for further research under Physical Internet-enabled settings such as aiming universal hyperconnectivity in transportation, distribution, production and supply.*

Keywords: *Product Availability Optimization, Hyperconnected Networks, Product Substitution, Inventory Transshipment, Retail Networks, High-Value Products, Product Assortment*

1 Introduction

Incomplete product availability deems inevitable in retail networks for reasons such as uncertain demand, forecast errors, budget, and space-related limitations. It results in the customers purchasing a substitute product when a satisfactory alternative is available in stock (Fitzsimons, 2000; Gruen et al., 2002; Campo et al., 2004) or lost sales if none of the available products meets the customer's expectations (Derhami and Montreuil, 2019). In either case, customer satisfaction suffers through in the latter case, it suffers more drastically, and both the product manufacturer (brand) and the retailer incur direct and indirect costs associated with lost sales. This along with the customer-centric marketing strategies that attempt to provide the customers with their desired products within a satisfactory time in any location, force retail networks to employ smart innovative approaches to prevent or at least reduce incomplete product availability.

Retail centers offering high-value substitutable products such as cars, recreational vehicles, high-end electronics, luxury clothing and jewelry usually employ inventory transshipments or on-demand priority orders from distribution centers, depots or manufacturing facilities to satisfy the demand for out-of-stock products. This is mostly because on one side the sales profit justifies the cost and hassles of a transshipment and on the other side customers in such markets may be willing to wait up to a reasonable time to receive their desired product (Montreuil et al., 2019). Today, such retail networks are rapidly moving towards hyperconnected distribution networks where the flow of information and goods between multi-party retail centers, distribution centers and manufacturer allow efficient utilization of inventory across the network (see Figure 1). In such environment, in-stock availability does not fully reflect product availability in a retail center because other resources such as manufacturer, depot, and inventory of other retailers can be exploited on-demand to satisfy customer demand. This makes the assortment planning decision more challenging because, in addition to stock, dealerships ought to account for the available products through the network to maximize their sales.

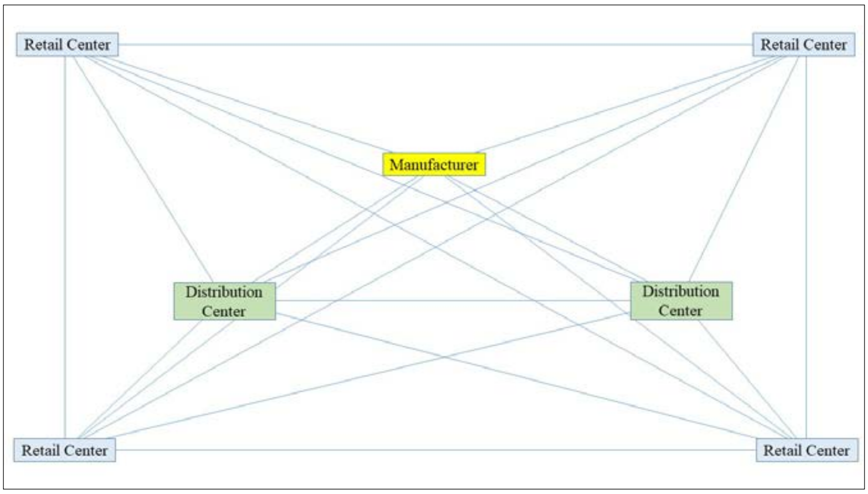

Figure 1: Illustration of a Hyperconnected Retail Network of High-Value Product Manufacturer

Montreuil et al. (2019) proposed a new approach to estimate product availability for an interconnected network of dealerships. They defined a new Key Performance Indicator (KPI) termed Product Availability Ratio (PAR) that measures the readiness of a dealership to satisfy upcoming customers by taking into account product demand share estimates, product substitution probability, and network availability of products.

In this paper, we develop a mixed integer program using the PAR model proposed by Montreuil et al. (2019) to find the optimal replenishment orders in the context of dealerships placing frequent replenishment orders under stochastic demand and customer substitution. Our model determines the set of products that a group of interconnected dealerships should replenish to maximize their product availability and consequently, customer satisfaction. It simultaneously solves the assortment plan for all dealerships in the network and therefore considers the interactions and effects of dealer orders on one another. The proposed model differs from the conventional assortment planning problem in that it concurrently accounts for product substitution, the inventory transshipment policies employed frequently by dealerships to satisfy the demand for an out-of-stock product, and the willingness of customers to wait to receive their desired product. The simulation results for a case of recreational vehicles show that the proposed model can achieve 30% sales increase while maintaining the same inventory level.

The remainder of the paper is structured as follows. Section 2 reviews pertinent papers, describes the gap in the existing literature and explains the contribution of this paper. In section 3, we briefly present the PAR estimation model developed by Montreuil et al. (2019) and describe the mathematical formulation of our optimization model. Section 4 presents the simulation results of a case study, and section 5 provides concluding remarks and avenues for further research.

2 Literature review

In a customer-centric retailing environment taking into account product availability for high-value high-variety products, determining what to store where is a key decision. Extensive research on assortment and inventory decisions in retailing have been conducted to solve this problem. Pentico (1974) demonstrated a one-dimensional assortment planning problem regarding the sequence of customer arrivals under stochastic demand. Then, Pentico (1988) extended his research to a two-dimensional assortment planning problem that allows product substitution while it is not the case in the one-dimensional assortment planning problem, using an Economic Order Quantity (EOQ) model under deterministic demand. Ryzin and Mahajan (1999) analyzed a category-based assortment problem using a multinomial logit model (MNL) to describe the consumer choice process. Chong et al. (2001) presented an empirically-based modeling framework using a nested MNL model to address the complexity of managing a category assortment. Gaur and Honhon (2006) proved that products should be equally spaced using a locational choice model to address customer demand under a single-period assortment planning. This paper as contrasted with the above papers, investigates a product availability maximization focused multi-dimensional network based assortment planning problem taking in account estimated demand share of each product and customer substitution probability.

One key component for the assortment planning problem in our study is customer's substitution behavior. Numerous studies focused on stock-out-based substitution behavior whereby customer decision depends on the products available in stock at the time of her visit to the store. Kok and Fisher (2007) implemented a case study of a supermarket chain to observe the substitution behavior and demand for products in each store. Honhon et al. (2010) developed a dynamic programming algorithm for the optimal assortment and inventory levels in a single-period problem with stock-out-based substitution. However, relatively little is studied on dynamic substitution taking into account all the available products in the network as potential resources so as to best meet stochastic demand.

Inventory transshipment is exploited as an alternative and complements to dynamic substitution in this research, as a retailer may exploit alternative sources for the demanded product and for substitutes depending on the lead time acceptable by the customer. Inventory transshipment has long been identified as a key leverage in the literature. Zhao et al. (2008) analyzed the optimal production and transshipment policy for a two-location make-to-stock queueing system. Fang and Cho (2014) showed how inventory decisions change when transshipment of excess inventory is allowed by studying a cooperative game among multiple companies. Wee and Dada (2005) developed a formal model for transshipping inventory in a retail network using the stock either from a warehouse or from another retailer that has excess stock. In this paper, we extend by assuming that all retailers may take advantage of inventory transshipment, and that they cooperate to maximize network-wise product availability for all customers visiting any dealership in the network, while insuring satisfying retailer-specific availability.

In recent years, more studies have been conducted on product availability to better satisfy uncertain demand. By smartly deploying products in the network inventory, sales increase while keeping the same inventory level is made possible. Chiang (2008) showed how customers' stock-out based substitution can make an impact on product availability when both a supplier and its retailer behave to optimize their own profit. Ervolina et al. (2009) proposed a mathematical optimization model to manage product availability in an assemble-to-order supply chain with multiple customer segments by a case study. In our research on product availability optimization, we benefit by comparing the simulation results by the proposed-model-based orders and the actual dealer orders for a case of recreational vehicles.

Physical Internet plays a key role in facilitating fast and efficient order replenishment and inventory transshipment in the context of this research. Recent studies have demonstrated how the new concept of Physical Internet enables to shift toward much more distributed hyperconnected transshipment. Montreuil B. (2011) emphasized live open performance monitoring of all Physical Internet actors and entities as one of the key characteristics to define the Physical Internet vision, which focuses on key performance indices of critical facets such as speed, service level, reliability, safety, and security. Exploiting real-time inventory identification between retail centers and fast replenishment, we evaluate the new KPI termed PAR in hyperconnected retail networks in this study. Hakimi et al (2012) and Sarrai et al (2014) showed by simulation that the Physical Internet-based transportation reduces 20-32% of the total traveled distance in a case of an open logistics web in France. In this study, considering the customer's acceptable waiting time that facilitates nearer transshipments through hyperconnected transportation, we attempt to find the best fitting combination of inventory deployment for all retail centers in the network.

This paper contributes to the multi-dimensional assortment planning literature for high-value products in that inventory transshipment between dealerships and customers' willingness to wait for their desired product are considered throughout the hyperconnected network. On top of that, this research proposes a novel approach that optimizes product availability under the Physical Internet-enabled hyperconnected retail networks, and investigates the correlation between the product availability of dealerships and the corresponding successful sales.

3 Methodology

In this section, we first present the components of the PAR model developed by Montreuil et al. (2019) for product availability estimation in an interconnected network of retailers. Then, we describe our proposed optimization model to solve the assortment planning problem with the objective of maximizing product availability while considering the possibility of inventory transshipment.

3.1 Product availability ratio (PAR)

We consider product availability ratio as a key measurement to assess the readiness of retail centers to satisfy the upcoming customers. Considering a hyperconnected network of dealerships, it uses stochastic demand shares, and accounts for possible inventory transshipment as well as customers' willingness to accept a substitute product and to wait some time so as to receive a satisfactory product.

The fundamental components utilized to compute the PAR are (a) inventory at each dealer, (b) substitution matrix from substitution product to demanded product, (c) product transfer time from a dealer to another, (d) daily product demand share at each dealer, and (e) the proportion of customers willing to wait for the desired product. Components (a), (b), and (c) are inputs to the model while components (d) and (e) are derived from experimental results, as described in Derhami and Montreuil (2019) and Montreuil et al. (2019). The PAR computation starts with truncating the original substitution matrix of products by given thresholds based on the assumption that none of the customers would purchase any substitute product whose substitution level for the desired product is below a certain threshold (Montreuil et al., 2019). The threshold for each product is also input to the model. It varies according to the main characteristics of the product and its retailing price. In general, it may be assumed that customers who want a more luxurious and costly item might be pickier, so their expectations relative to the fitness of a substitute product for it to be satisfactory would be higher than if they would be wanting less costly items (Montreuil et al., 2019). The substitution matrix truncating process is expressed below:

$$F_{pp'} = f_{pp'}\ if\ f_{pp'} > t_p, else\ 0 \qquad \forall p, p' \tag{1}$$

where $F_{pp'}$ is the considerable substitution of product p' for demanded product p, $f_{pp'}$ is the original substitution fitness of product p' for demanded product p, and t_p $(0 \leq t_p \leq 1)$ is the threshold for considering substitution for a client-demanded product p. When product p' is not available now at the dealer d visited by the customer, then its transfer time form its current dealer d' to dealer d must be taken into consideration. So we transform the considerable substitution matrix into a time-based substitution matrix as follows:

$$S_{pdp'd'\tau} = F_{pp'}\ if\ p_{dd'} \leq \tau, else\ 0 \qquad \forall p, d, p', d', \tau \tag{2}$$

where $S_{pdp'd'\tau}$ is the time-based substitution fitness of product p' from dealer d' in time τ as a substitute for demanded product p to dealer d, and $p_{dd'}$ is the transfer time (in days) of a unit of product from dealer d' to dealer d. Now considering the existing inventory at each dealer, we get the best considerable availability for all possible demands from each product p, each dealer d, and each customer waiting time τ as follows:

$$A_{pd\tau} = \max_{p'd'}(S_{pdp'd'\tau} * i_{p'd'}) \qquad \forall p, d, \tau \tag{3}$$

where $A_{pd\tau}$ is the time-based best considerable product availability for product p at dealer d in time τ, and i_{pd} $(i_{pd} \in \{0,1\})$ is the existing inventory state of product p at dealer d. The PAR is then computed by taking into consideration the estimated demand shares per product per dealer, and the customers' willingness to wait for their desired product, as formally expressed below:

$$PAR = \sum_{\tau} v_{\tau} \sum_{pd} d_{pd} A_{pd\tau} \tag{4}$$

where v_{τ} is the share of the customers' willingness to wait for their desired product until time τ and d_{pd} $(0 \leq d_{pd} \leq 1)$ is the expected demand share of product p at dealer d in the region, and $\sum_{pd} d_{pd} = 1$.

3.2 Product availability optimization model

We here address the problem of maximizing the product availability ratio of all dealerships by deciding which product to order in the context that each dealer takes into account the product substitutions and exchanges within the network. Hence, all dealers can take advantage of the network inventory so as to maximize the availability of a customer-targeted product at her selected dealer, as a surrogate to minimizing unsatisfied customers and lost sales. We hereby formalize this problem through introducing a PAR optimization model.

3.2.1 Input parameters

$a_{pp'}$: Product substitution availability of product p' for product p (1 if product p' is substitutable for product p, 0 otherwise), $a_{pp'} \in \{0,1\}\ \forall p, p'$

d_{pd} : Expected demand share [0,1] of product p at dealer d in the region, $\sum_{pd} d_{pd} = 1$

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

$s_{pdp'd'\tau}$: Substitution fitness of product p to dealer d offered by product p' from dealer d' in time τ

v_τ : Expected share [0,1] of customer’s willingness to wait for her desired product until time τ, $\sum_\tau v_\tau = 1$

3.2.2 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 the inventory of dealer d, 0 otherwise

O_{pd} : 1 if product p is ordered by dealer d, 0 otherwise

3.2.3 Objective function

The objective is to maximize the total weighted product availibilty of dealers given the expected share of customers willing to wait up to a specific time for a satisfactory product, and the expected demand share of product p at dealer d in the region. It can be expressed as:

$$\text{Maximize: } PAR = \sum_\tau v_\tau \sum_{pd} d_{pd} A_{pd\tau} \tag{5}$$

3.2.4 Constraints

$$I_{pd} = O_{pd} + i_{pd} \qquad \forall p, d \tag{6}$$

$$\sum_p I_{pd} \leq m_d \qquad \forall d \tag{7}$$

$$F_{pdp'd'} \leq 1 - a_{pp'} I_{p'd} \qquad \forall p, d' \neq d, p' \tag{8}$$

$$F_{pdp'd'} \leq I_{p'd'} \qquad \forall p, d, p', d' \tag{9}$$

$$\sum_{p'd'} F_{pdp'd'} \leq 1 \qquad \forall p, d \tag{10}$$

$$A_{pd\tau} = \sum_{p'd'} s_{pdp'd'\tau} F_{pdp'd'} \qquad \forall p, d, \tau \tag{11}$$

$$F_{pdp'd'} \in \{0,1\} \qquad \forall p, d, p', d' \tag{12}$$

$$I_{pd} \in \{0,1\} \qquad \forall p, d \tag{13}$$

$$O_{pd} \in \{0,1\} \qquad \forall p, d \tag{14}$$

By constraint set (6), the total sellable inventory becomes eqaul to the sum of the order and the current inventory. Constraints (7) restrict the portfolio size for each dealer. By constraints set (8), the offered substitution product p' from dealer d' can be chosen for demanded product p at dealer d only if there is no substitutable product p' at dealer d; these constraints are made for this optimization model to represent the actual dealer behaviors such that dealer does not consider inventory transshipment from other dealers if it has a substitutable product in its stock for demanded product. By constraints (9), product p' at dealer d' can be a substitute for demanded product p to dealer d only if product p' is in the inventory at dealer d'. Constraints

(10) ensure that only one product from all products at all dealers can substitute for demanded product p at dealer d. By constraint set (11), product availablity of product p at dealer d in time τ is computed such that the binary variable $F_{pdp'd'}$ selects the best time-based substitution to enable the maximum product availability. Constraints (12), (13), and (14) ensure that those variables are binary.

4 Case study

The case company, specialized in recreational vehicles including off-road vehicles and snowmobiles, currently operates with more than five hundred dealers in North America and is one of the top manufacturers in this industry. Dealers are businesses distinct from the manufacturer. Many dealership businesses operate a single dealer site, while some operate a few dealer sites. When facing a demand by a customer for a product not in its inventory, a dealer has the capability of investigating whether alternative sources within a satisfactory distance have the demanded product or a substitute one in stock, and to engage in transshipping a product from another source (e.g. dealer). The baseline for this experiment has each dealer deciding independently upon its inventory replenishment decisions without formally considering the substitution and transshipment options, and ignoring product availability ratio performance.

In order to test the performance of the proposed optimization model in this case study, a simulation-based experiment has been designed in a way that dealers are allowed to make an order on a daily basis and that with fast-replenishment the ordered products are delivered by early next morning before the dealers begin to operate. Seventeen dealerships in one state and 102 products of a certain category of vehicles are selected for this experiment. The simulation period is set to six business days in a given week in year 2018, and overall regional demand is set to be stemming around four customers daily, each demanding a specific product. The dealer visited by a customer is randomly identified, based on estimated dealer demand share within the region. The product demanded by the customer at the dealer is also randomly identified based on the given expected demand share per product per dealer. Each day the dealerships order products to replace those sold. A scenario is generated to correspond to a 6-day week of specific customer demand. In this paper, we provide exploratory results based on a twenty-scenario experiment.

We use Monte Carlo simulation as shown in Figure 2 to investigate the performance of our proposed methodology with the baseline approach. The 20 scenarios by simulation are generated using MATLAB software while the PAR optimization model is run using a developed Java software, exploiting the CPLEX optimization software package. In each scenario of the simulation, each customer visits one retail center, expresses her demanded product, and states how long she is willing to wait for receiving a satisfactory product. If the retailer can provide a satisfactory product (i.e., the product whose substitution level for the demanded product is above the threshold) either by its own inventory or by inventory transshipment from other retailers within the time that the customer is willing to wait, then a successful sale occurs. Otherwise, the retailer loses the sale. After the available substitution product searching process, as marked with the blue dotted line in Figure 2, is finished, the retailer makes an order at the end of the day by different order policies that are explained in the next paragraph. Then, all this process is repeated for the assigned simulation period, and the resulting scenario is generated.

We design different three order policies for dealerships to evaluate the performance between the current business model of the case company and the proposed model. The three alternatives for the experiment are:

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

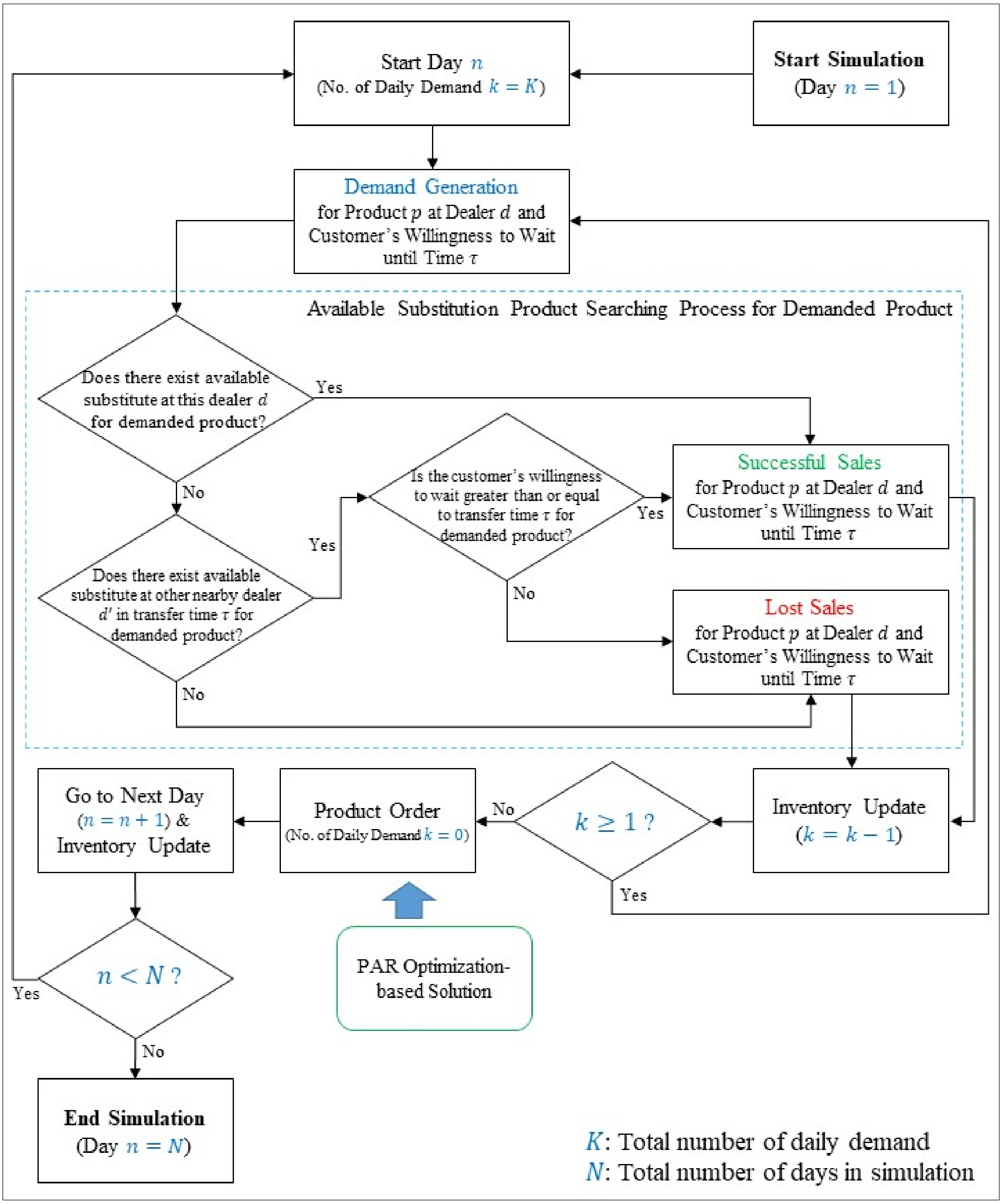

Figure 2: Diagram of Simulation Model Generating Hyperconnected-Dealer-Network-based Scenarios

Note that alternative 1 corresponds to the company's current typical operation so the actual dealer orders during the simulation period are identified: dealers make orders independently and locally, not considering customers' substitution behavior nor the potential of inventory transshipment. Alternative 2 is designed to evaluate the single dealer focused product availability whereas alternative 3 is the proposed operation scheme discussed in section 3. In alternative 2, dealers consider customers' substitution behavior but do not take into account the potential of product transshipment, while dealers consider all the three factors in alternative 3. We generate the initial inventory for alternatives 2 and 3 based on single dealer focused PAR optimization and hyperconnected PAR optimization, respectively but keep the inventory level the same as alternative 1.

Demand shares of products are forecast daily using exponential smoothing, adjusted so the total of estimated shares always equals one. We used the historical sales log data of the case company in the given region and the expected lost sales ratio in order to estimate the realized demand shares (Derhami and Montreuil, 2019), which become data input to product demand share forecast.

4.1 Quantitative analysis

To evaluate how much improvement our developed method can make on dealers' performance and provide better insight, we numerically and graphically analyze the experimental results.

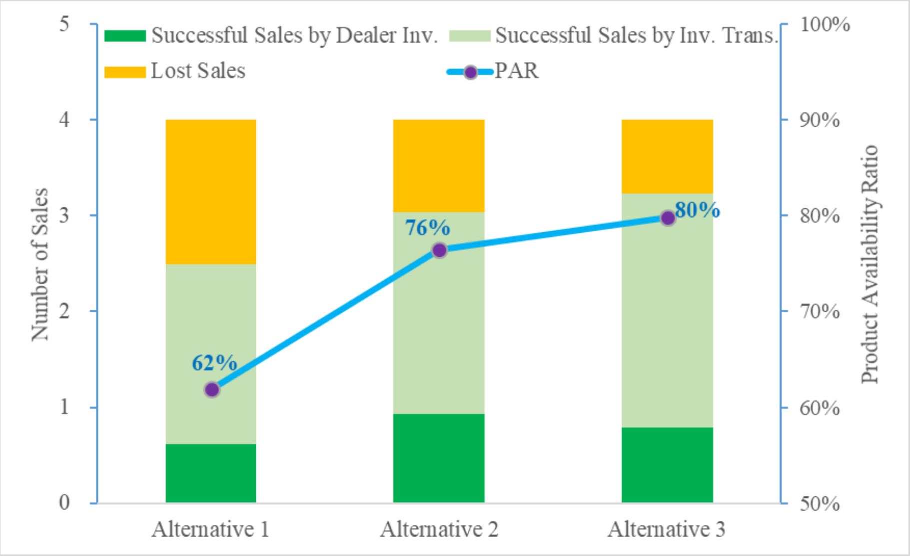

Figure 3: Daily Average Successful Sales and Lost Sales along with PAR

Figure 3 shows the resulting daily average successful sales and lost sales, along with the daily average PAR result from the 20 scenarios generated by each alternative. Maintaining the same dealer inventory size at retail centers as alternative 1, alternative 2 and 3 result in significantly higher PAR than alternative 1. This can be interpreted as dealers having significantly higher chance to meet uncertain customer demand in alternative 2 and 3 than in alternative 1. Since dealers in alternative 2 always attempt to maximize their own PAR without taking into consideration the potential of the network-driven product transshipment, even though it is allowed, the average daily PAR improvement is restricted. Exploiting hyperconnected-network-based PAR optimization, alternative 3 increases PAR by 29% in contrast to baseline alternative.

The sales results derived from customer demands indicate that dealers can make more sales under the PAR optimization policy. Exploiting alternative 2 and 3, the average daily sales increase by 22% and 30% as contrasted with baseline alternative 1. Interestingly, the successful sales made by the dealer's inventory rather than the inventory of other dealers is higher in alternative 2 than those in alternative 3. This is due to the fact that in alternative 2, dealers always attempt to be ready for the next visiting customers as best as possible with their own inventory by maximizing their standalone product availability. In contrast, alternative 3 enables the best total average daily sales as it better deploys products in the network and consequently, results in more inventory-transshipment-based sales. The average daily lost sales ratio of each alternative resulting from the 20 scenarios is 38%, 24%, and 19%, respectively for alternatives 1 to 3.

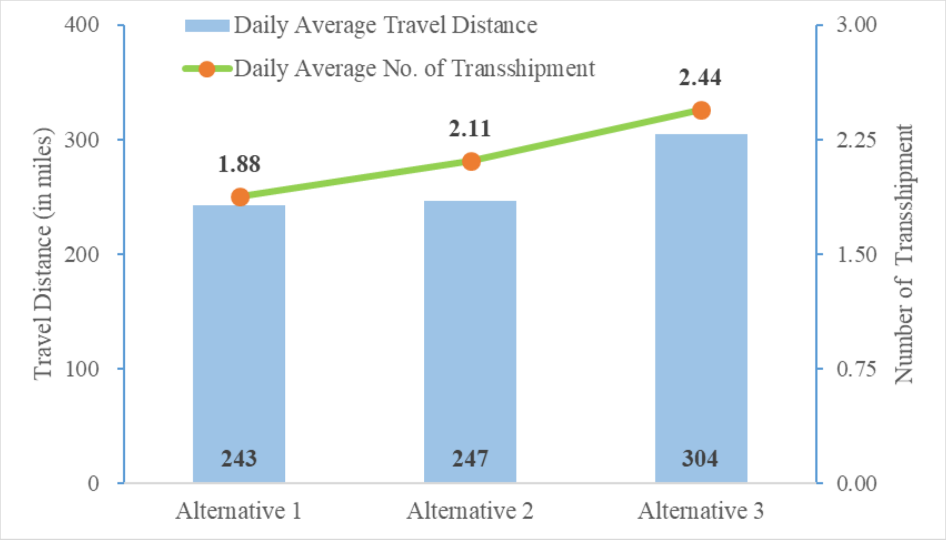

Figure 4: Daily Average Number of Transshipment and Corresponding Travle Distance

Figure 4 presents the daily average number of transshipment occurrence and the resulting daily average travel distance. As expected from the result shown in Figure 3, the most travel for product transshipment occurs in alternative 3 so as to best meet the customers' demand by employing the network inventory. Also, a higher number of transshipments occur in alternative 2 than in alternative 1 as in the region there is inventory of more PAR-contributing products in alternative 2 and thus this contributes to meeting uncertain demand to some degree. However, the total traveled distance differs only slightly between alternative 1 and 2. This is because in alternative 2, a few big dealers with higher inventory are ordering some highly substitutable products, which become available for transshipping to other relatively small dealers, whereas the product transshipments in alternative 1 occur more randomly and thus, result in a greater traveled distance per unit of product transshipment.

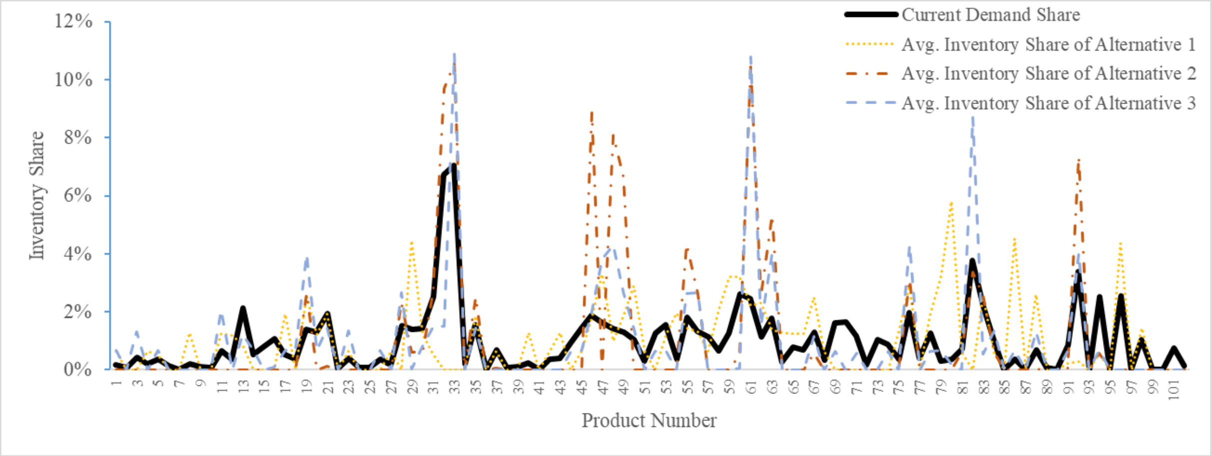

Figure 5: Daily Average Network Inventory Share

Figure 5 shows the share of the average network inventory per product for each alternative, compared with the current demand share per product in the region. There are some significantly higher inventory shares than the current demand shares for certain products in alternatives 2 and 3, while inventory shares over 6% for any product do not exist in alternative 1. This is due to the fact that keeping more of highly substitutable products contributes to enabling high PAR, thus it ends up in alternatives 2 and 3 with ordering more of those products than their demand shares. This does not happen in alternative 1 that does not consider production substitution when ordering replenishments. Because of product substitution, alternatives 2 and 3 show similar high inventory share patterns for certain highly substitutable products such as products 32, 33, 61, and 63. However, they significantly differ in other highly substitutable products, including products 46, 48, and 49. This is because in alternative 3, dealers consider the potential of inventory transshipment when they place an order, and consequently do not order too many of them if the products are stored at other nearby dealers, whereas the potential of inventory transshipment is never considered in alternative 2.

5 Conclusion

In this paper, we address the optimization of dealer replenishment decisions in planning their assortment so as to maximize the Product Availability Ratio (PAR) defined by Montreuil et al (2019). We formalize the problem as discrete optimization model capable of tackling PAR optimization for a hyperconnected network of dealers offering a wide-variety portfolio of substitutable high-value products. We provide exploratory empirical results based on a Monte Carlo simulation for a case study of a leading manufacturer of recreational vehicles.

By switching the emphasis from inventory to availability, the paper originally contributes to the literature associated with assortment planning, inventory transshipment, customers' substitution behavior, and product availability. Importantly, the paper takes into account inventory transshipment among dealerships and customers' willingness to wait to receive their desired product.

The paper provides insights on how such an advanced hyperconnected system can benefit all retailers in the network by increasing readiness to respond to customer demand, and inducing sales growth and customer satisfaction growth. The simulation results notably show that our developed model can achieve 30% sales increase while keeping the same inventory level by smartly determining the set of products for a group of interconnected dealerships. This is mainly because the proposed model induces the network inventory shares match to the network-based product demand shares, while adjusting to take into consideration the fact that certain products are satisfactory substitute to several others.

In regard to further research, more meaningful results can be obtained in future work by further investigating 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. In addition, there should be deeper investigation of the gains in PAR, sales, profitability and sustainability performance enabled by Physical Internet hyperconnectivity. Notably, the reduction of required inventory to achieve high PAR given faster and cheaper hyperconnected transportation and distribution, with digitally transmitted real-time information and smart deployment optimization. There is also potential to be explored relative to production and supply, by feeding dealers directly from factories and suppliers instead of only relying on inventoried products.

References

- Campo K., Gijsbrechts E., Nisol P. (2004): Dynamics in consumer response to product unavailability: do stockout reactions signal response to permanent assortment reductions? *Journal of Business Research*, 57, 834-843.
- Chang W. K. (2008): Product availability in competitive and cooperative dual-channel distribution with stock-out based substitution. *European Journal of Operational Research*, 200, 111-126.
- Chong J. K., Ho T. H., Tang S. C. (2001): A Modeling Framework for Category Assortment Planning. *Manufacturing & Service Operations Management*, 3(3), 191-210.
- Derhami S., Montreuil B. (2019): Estimation of potential lost sales in retailers of high-value substitutable products. *Under review in Production and Operations Management.*
- Ervolina T. R., Ettl M., Lee Y. M., Peters D. J. (2009): Managing product availability in an assemble-to-order supply chain with multiple customer segments. *OR Spectrum*, 31, 257. https://doi.org/10.1007/s00291-007-0113-4
- Fang X., Cho S. H. (2014): Stability and Endogenous Formation of Inventory Transshipment Networks. *Operations Research*, 62(6), 1316-1334.
- Fitzsimons G. J. (2000): Consumer response to stockouts. *Journal of Consumer Research*, 27, 249-266.
- Gaur V., Honhon D. (2006): Assortment Planning and Inventory Decisions Under a Locational Choice Model. *Management Science*, 52(10), 1528-1543.
- Gruen T. W., Corsten D. S., Bharadwaj S. (2002): Retail out-of-stocks: A worldwide examination of extent, causes and consumer responses. *Technical Report Grocery Manufacturers of America*, Washington, DC.
- Hakimi D., Montreuil B., Ballot E. (2012): Simulating a Physical Internet Enabled Logistics Web: the Case of Mass Distribution in France, *ISERC 2012 Proceedings*, 2012/-5/19-23
- Honhon D., Gaur V., Seshadri S. (2010): Assortment Planning and Inventory Decisions Under Stockout-Based Substitution. *Operations Research*, 58(5), 1364-1379.
- Kok A. G., Fisher M. L. (2007): Demand Estimation and Assortment Optimization Under Substitution: Methodology and Application. *Operations Research*, 55(6), 1001-1021.
- Montreuil B. (2011): Towards a Physical Internet: meeting the global logistics sustainability grand challenge. *Logistics Research*, 3, 71-87.
- 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*.

- Pentico D. W. (1974): The assortment problem with probabilistic demands. *Management Science*, 21(3), 286-290.
- Pentico D. W. (1988): The discrete two-dimensional assortment problem. *Operations Research*, 36(2), 324-332.
- Ryzin V. G., Mahajan S. (1999): On the Relationship Between Inventory Costs and Variety Benefits in Retail Assortment. *Management Science*, 45(11), 1496-1509.
- Sarraj R., Ballot E., Pan S., Hakimi D., Montreuil B. (2014): Interconnected logistic networks and protocols: simulation-based efficiency assessment, *International Journal of Production Research*, 52:11, 3185-3208.
- Wee K. E., Dada M. (2005): Optimal Policies for Transshipping Inventory in a Retail Network. *Management Science*, 51(10), 1519-1533.
- Yucel E., Karaesmen F., Salman F.F., Turkay M. (2009): Optimizing product assortment under customer-driven demand substitution. *European Journal of Operational Research*, 199, 759-768.
- Zhao H., Ryan K. J., Deshpande V. (2008): Optimal Dynamic Production and Inventory Transshipment Policies for a Two-Location Make-to-Stock System. *Operations Research*, 56(2), 400-410.