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Assortment Planning under Uncertainty in Physical Internet Enabled Supply Chains

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Conference Domain Fitness: *Our contribution advances IPIC 2024's agenda by proposing a robust assortment planning model for the Physical Internet, enhancing supply chain sustainability and resilience. It integrates PI principles and technological innovations, enabling dynamic, efficient logistics and retailing ecosystems. This aligns with IPIC's focus on hyperconnected networks and the facilitation of emergent, scalable Physical Internet applications, supporting the conference's commitment to innovative, sustainable logistics solutions.*

Physical Internet (PI) Roadmap Fitness*: Select the most relevant area(s) for your paper according to the PI roadmaps adopted in Europe and Japan:* ☐ *PI Nodes (Customer Interfaces, Logistic Hubs, Deployment Centers, Factories),* ☐ *Transportation Equipment,* ☐ *PI Networks,* ☐ *System of Logistics Networks,* ☒ *Vertical Supply Consolidation,* ☐ *Horizontal Supply Chain Alignment,* ☐ *Logistics/Commercial Data Platform,* ☐ *Access and Adoption,* ☐ *Governance.*

Targeted Delivery Mode-s*:* ☒ *Paper,* ☐ *Poster,* ☐ *Flash Video,* ☒ *In-Person presentation*

Research Contribution Abstract

Assortment decisions, typically led by the marketing department, are intricately linked to operational decisions across procurement, production, and inventory planning. With increasing production costs and resource constraints, assortment planning decisions need to be made with supply chain considerations in mind. Traditional retail models must innovate in this context; the Physical Internet (PI) offers a paradigm aiming to transform physical goods logistics to reflect the efficiency of the digital internet.

Within this framework, we explore the assortment planning problem under certainty and supply chain capacities, focusing on leveraging vertical integration with a customer-driven product substitution approach that aligns with the principles of the Physical Internet. We consider a manufacturer-retailer operating in a make-to-stock environment, with assortment decisions made over a planning horizon. Addressing supply disruptions and unpredictable demand with multi-period look-ahead forecasts, we introduce a multi-stage stochastic programming model. Our model accounts for procurement and production capacity constraints, ensuring that product offerings not only meet customer demand profitably and feasibly, optimizing expected profit.

By reviewing the assortment and adjusting decisions for each review period, we transition from a traditional static approach to a more dynamic approach, equipping retailers with enhanced agility in responding to supply and demand variability—a crucial capability in the current volatile and disruption-prone retail landscape. We aim to maximize profitability by aligning product availability with customer preferences, thereby increasing sales opportunities. Additionally, inventory efficiency can improve, with the potential to reduce overstock and waste. Better resource utilization allows for a shift towards more sustainable operations and waste reduction, aligning with broader environmental goals. We then explore enhancing this model using PI principles for superior dynamism and responsiveness. The PI approach affords agility analogous to data transit on the digital internet, with the potential for real-time adjustment to market shifts, enabling a transition from a rigid, forecast-driven planning approach to a real-time, demand-driven model that maximizes resource utilization and customer value.

The PI levers applicable to our problem context include:

1. Interconnectivity: By linking assortment planning decisions with real-time supply chain information, the model facilitates a responsive planning process that can quickly adapt to changing market conditions and consumer behaviors.

2. Standardization: Adopting PI's standardized interfaces and protocols ensures compatibility and ease of integration across different systems and stakeholders in the supply chain.

3. Modularization: Utilizing the concept of modular product offerings, the model allows for flexible assortment adjustments, enabling retailers to offer product substitutions that align with consumer preferences and available inventory.

Additionally, we explore the concept of product interconnectivity through substitution within the PI framework. Traditional models view products as independent entities, while PI sees them as interconnected nodes within a larger network. This perspective allows for substitutions that are strategically planned based on customer preferences and supply chain efficiencies. Our problem context and vertical integration allow for acknowledging customer-driven product substitution from the procurement and production stage to not only better meet customer demand but also reduce excess inventory and mitigate the risk of stock-outs. Such alignment of customer preferences and supply chain efficiency not only generates profit but also resonates with the PI's objectives of reducing waste and improving resource utilization through interconnected logistic networks.

We present results derived from empirical data provided by an e-commerce furniture manufacturer-retailer that showcase the potential for significant improvements in expected profit margins. The case study illustrates the practical implications of our model, focusing on how it can drive a more resilient and responsive retail structure.

To demonstrate the impact of PI, we provide a conceptual illustration comparing the following scenarios: traditional static and deterministic assortment planning, our proposed model, and the proposed model leveraging the PI. In the traditional scenario, assortment decisions are static, based on historical data and forecasts, possibly leading to overstocking or stock-outs due to mismatches in supply and demand. Conversely, the PI model facilitates a fluid decision-making process, where real-time data informs dynamic assortment adjustments, ensuring optimal stock levels and satisfying consumer demands for product variety and availability. We show how real-time interconnectivity and substitution capabilities can lead to more resilient supply chains and higher customer value.

The shift towards a PI framework in assortment planning represents a profound change, demanding a reassessment of conventional retail strategies. Realizing the full benefits of the PI requires an overhaul of retail logistics, tackling complexities and computational challenges of dynamic, uncertainty-based assortment planning.