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Value of Physical Internet-driven Collaborative Management in Multi-Actor Supply and Distribution Networks

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Conference Domain Fitness: *Our contribution lies in enhancing the societal, economic, and environmental efficiency, resilience, and sustainability of fulfilling humanity's needs for societally critical products. Our work investigates the potential of leveraging Sharing Economy, Equitability, and Fairness principles and practices. Finally, our contribution paves the way for shaping, enhancing, and enabling the further emergence and large-scale implementation and adoption of the Physical Internet across industries and territories, at all scales from within facilities, to urban and rural areas, regions, countries, continents, spanning the whole planet and beyond through space.*

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

Societally Critical Products (SCP) are survival-essential products characterized by high demand variability, limited availability, time-sensitive and require equitable distribution for the welfare of overall population (Shaikh et. al, 2023a). As an example, the COVID-19 pandemic induced a sudden surge in the demand for personal protective equipment (PPE) such as masks, gloves, and sanitizers. Since early 2020, we experienced a severe shortage of PPE required by healthcare workers (Emanuel et al., 2020; Livingston et al., 2020). Furthermore, a supply-demand imbalance was observed for PPEs due to panicked market behavior, lack of rationing mechanisms for users, and a dysfunctional organizational incentivization to minimize cost rather than maintaining adequate inventory levels to safely navigate potential disruptions (Rodgers et. al, 2020).

As a case study, we consider a living lab initiative started in May 2020 by Physical Internet Center at Georgia Institute of Technology (Shaikh et. al, 2023a). Prior to the pandemic, each lab on campus autonomously managed their own PPE supply, oftentimes stocking for the upcoming 6-months to a year. Due to the perceived supply scarcity at the onset of the pandemic, the initiative was launched towards safeguarding the ongoing research and ensuring individual safety on campus. Furthermore, as a societal responsibility, it is essential to maintain SCP inventories at a sustainable level, ensuring least impact on the global and regional demand-supply disruption-induced imbalance.

As part of the living lab initiative, we developed and implemented a novel quasi-autonomous supply and distribution system (Shaikh et. al, 2023b). Through this system, we reverse the fundamental premise that *each lab on campus is solely responsible for ordering PPE to support availability to their researchers*, to a new premise where *most of the times nobody on campus has to order PPEs to ensure their adequate and persistent availability in their realm (e.g. lab, building), as long as they simply keep on reporting their number of active users, PPE consumption and inventory*. Overall, the system efficiently served demand from users in over 200 labs across 45 buildings on campus.

Learning from the operational challenges, (Shaikh et. al, 2023b) highlighted the benefits of utilizing Physical Internet (PI) principles towards autonomous operations. Significant improvement was observed in overall inventory levels while maintaining service level utilizing tracking-enabled modular containers (Montreuil et. al, 2015), autonomous dispensing using smart lockers (Faugere and Montreuil, 2017), and autonomous environment-conscious mobility mediums.

In this paper, we evaluate the benefit of adoption of our collaborative PI-driven supply and distribution management approach, using multi-agent-based simulation testing. We consider 3 scenarios, where: (a) all actors autonomously manage their SCP inventory; (b) half of the actors adopt the proposed approach, and rest operate autonomously; and (c) all actors collaboratively manage their inventory adopting the proposed approach. We utilize results from previously conducted surveys to get user behaviors in the autonomous and collaborative scenarios. Furthermore, we test the scenarios under varying degrees of supply disruption.

Overall, the contribution of our paper is the empirical testing of the adoption of collaborative PI-driven supply and distribution system. To the best of our knowledge, there do not exist any studies highlighting the societal value of such an approach on the overall inventory, demand satisfaction, costs, and logistics-induced emissions. Furthermore, our work serves as the base for exploring the profound benefits for PI-driven collaboration among systems of such multi-actor networks.

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