Robust logistics service network design for perishable products with uncertainty on transportation time

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Physical Internet Roadmap *(*[Link](#)*): Select the most relevant area(s) for your paper:☐ PI Nodes, ☒ PI Networks, ☐ System of Logistics Networks, ☐ Access and Adoption, ☐ Governance.*

Contribution abstract

Disruptions in logistics, including local disruptions (technical issues, out-of-service warehouse, etc.) or mega-disruptions (pandemic, wars, earthquakes, etc.), have dramatically raised industrial practitioners' concern to the shipment delay which damages the logistics service quality. The problem is particularly sensitive to perishable products, e.g. fresh produce, vaccine, medicine, which are usually of short shelf life. It is significant to respect the shelf life since their value (or functionality) deteriorates remarkably with time. Delayed (or uncertain) logistics services can lead to deteriorating commodity quality even waste. Therefore, shippers of perishable products pursue robust solutions on product distribution to guarantee the service quality, including the freshness and on-time delivery under the uncertainty of transportation time.

This work from the shippers' perspectives investigates logistics service network design problem (LSNDP) under uncertainty. Traditional LSNDP aims to achieve the best tradeoffs between service quality and operational costs at the tactical planning level (Crainic, 2000). Based on that, this work integrates service selection with traffic distribution under a multi-modal transportation network with uncertain transportation time, where multi-modal transport services are combined together during transportation, i.e. maritime, air, railway and road way. However, the design of service timetable and frequency is not considered as we focus on route and service selection.

This work also aims to contribute to Physical Internet (PI), a new logistics paradigm suggesting global, open and interconnected logistics systems. Under a such paradigm which is fundamentally different to the current practices, it is possible to dynamically organize the logistics service even in the presence of disruptions. Previous works have shown that it may enable more flexibility, agility and delivery options to mitigate disruptions (Yang et al., 2017). This work investigates how PI can enhance LSNDP under uncertainty of transportation time.

Stochastic programming and robust optimization are the two common paradigms applied in the literature to deal within logistics uncertainty. Stochastic programming assumes that uncertainty can be described by exact probability distribution. Robust optimization, by contrast, assumes that uncertainty cannot be described explicitly by a such distribution, but only subject to a certain rang of deviation from the nominal value. In such setting, robust optimization is a paradigm studied for finding feasible and robust solution for all cases of the uncertainty, in other words, via using a *min-max* objective against the *worst-case*.

This work adopts robust optimization for several reasons. Firstly, in the presence of mega-disruptions or unpredicted disruptions, it is hard to catch the probability distribution information or the impacts which are required by stochastic programming. Secondly, due to the short and strict shelf life, and high sensitivity to lead-time, perishable product shippers have relatively lower tolerance to shipment delay and consequently incline towards conservative solutions on transportation service selection to realize the best tradeoff between costs and service quality. Given that, we apply classic robust optimization with budget-of-uncertainty proposed by (Bertsimas & Sim, 2003), which can control the conservative level of solutions. We assume that shippers know the information on the nominal value and the maximum deviation range of transit time (including transshipment time at hub and transportation time to the next hub) of each service on each arc called service-arc. The uncertainty of transit time is modeled as a deviation degree from the nominal value. The worst-case of uncertainty is modeled as the longest transportation time of each order. To control the conservatism level of the solution, a budget-of-uncertainty, pre-determined by decision-makers, is enforced on the total deviation degree of transit time on all service-arcs.

To find out the robust solutions, a Mixed Integer Linear Programming (MILP) model is proposed to minimize the total costs for shippers, which include transportation cost, transshipment cost, deteriorating cost and early or late delivery cost, with budget-of-uncertainty constraints. At this stage, numerical studies with fictive datasets have been conducted to validate the model, solved by CPLEX solver run on MATLAB. The first numerical results show that the developed model may deliver robust solutions on route and transportation service selection that satisfy all constraints (in particular all products must be delivered before the expiration date) while minimizing the total costs. Sensitivity analysis is carried out on the setting of budget-of-uncertainty, the degree of uncertainty, and shelf life of products, to investigate the tradeoffs between total costs and service quality. The next steps will focus on the real-life case data collection and tailed algorithm design. Managerial insights from the results on real cases will be provided to the industrial practitioners.

Reference

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