Structural uncertainty in supply chain simulation models

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To ensure that the right product is at the right place at the right time, supply chain visibility is crucial. Supply chain visibility relates to the ability to track parts, components, and products in transit from supplier to customer. There are many situations where only sparse data is available for supply chain visibility, for example when companies are reluctant to share data for competitive reasons. Another example is the class of counterfeit supply chains that is characterized by sparse data, uncertainty, and complexity since criminals mask their data and activities as much as possible. This makes it challenging to track counterfeit products in transit, thereby reducing supply chain visibility, and hampering the design of interventions to stop crime.

Simulation can help to improve visibility as it is a way to get insight in complex systems, recognizing relations, and exploring possible future states of the system. In these deeply uncertain and sparse data situations, both the parameters and the structure of the system, and therefore of the simulation model, can be (partly) unknown. For example, actors in the same supply chain have different perspectives on the operation of the supply chain. Structural uncertainty can be a major hurdle to gain understanding of supply chains that are characterized by complexity and uncertainty.

However, the inclusion of structural uncertainty in simulation models is a relatively unexplored topic. This raises the question: how can we include structural uncertainty into simulation models, specifically in the context of supply chains?

This research shows how to efficaciously account for structural uncertainty in supply chain simulation models using a model-driven exploratory modelling approach. We developed a model composer to create multiple configurations of a counterfeit Personal Protective Equipment supply chain using a so-called System Entity Structure conceptual model. By using various topological features of supply chains, the composer can generate a set of configurations of the supply chain simulation models. In this research, we compare this set with a ground truth simulation model to evaluate (1) the efficacy of the model composer to handle various forms of limited data, and (2) the effect of supply chain components (such as number of suppliers or travel distance) on structural uncertainty.

Results show that the above approach helps to model structural uncertainty in simulation models for supply chains in the case of limited data. The estimation of production times and international transport times are affected by structural uncertainty the most, since these times are highly dependent on the (partly unknown) structure and location of the actors.

This study can be used in future research to identify robust interventions over a large ensemble of supply chain simulation models with both parametric and structural uncertainty.

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