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Network on demand planning of Supply Chains towards Physical Internet

101 - Physical Internet

Abstract

Recent research in the Physical Internet and network design of supply chain literature stream indicates that a lot of resources are wasted in logistics. To mitigate this situation, the idea of Physical Internet aims to overcome these insufficiencies. This paper proposes a generic model for solving the location/ allocation and its parameter in real supply chains in order to minimize holding costs at minimum, transportation costs and handling costs. This model is verified by a real case in the supply chain.

Keywords:

network flow, location, allocation, demand, capacity, supply chain, physical internet

1. Introduction

The merging of the physical and the digital world is no longer restricted to social networks, but will significantly influence the way in which items are produced and distributed in the near future. These new requirements will not only have an impact on production planning decisions but also on concepts of managing supply chain networks, including the various means of transportation. These supply chain networks are in most cases poorly interconnected and lack consolidation (Sarraj et al. 2013). Montreuil (2011) states that the way physical objects are currently transported, handled, stored, realized, supplied, and used throughout the world is unsustainable economically, environmentally, and socially. Physical Internet has the goal of overcoming these weaknesses in the current supply chain networks. In the Physical Internet, goods travel in modular containers for the sake of interconnection in open networks. (Hakimi et al. 2010) introduces a simulation model for analyzing interlaced supply chain networks as the basis for Physical Internet to support managers in their decisions. (Hakimi et al. 2012) investigates the advantages of Physical Internet by a simulation study for fast moving consumer goods. The foreclosure and the rivalry within the logistic industry contribute to an overall inefficient and environmentally hostile system (Landschützer 2014). Similarly, these business practices lead to a significant number of empty rides in goods traffic. The EU alone in 2014 accounted for almost a quarter of all kilometers serviced by heavy-duty vehicles as being done by empty vehicles (European Commission 2014).

In this paper, the dynamic planning process of value networks (supply chains) is honed in on, whereby short term demand in the network nodes and edges is emphasized. Changes in demands of products also influence the business process, organization (staff), equipment (machines) and topological structure. This multi-structural approach increases the complexity in modeling, yet it exemplifies the connection between strategic and operational network planning. This paper will propose a generic framework for modeling real world location/allocation problems under stochastic demand.

2. Relevant literature

The management of the flow of goods between the point of origin and the point of consumption meeting customer requirements is the basic task of logistics. Typically logistics of physical products involves the integration of information flow, handling, production, packaging, transportation and warehousing. Planning of logistic networks is traditionally conducted by solving two separated and independent problems:

- warehouse/facility location and the corresponding allocation problem, which defines the inflexible structure of the network (Cooper 1963) see Figure 1.(1)
- customer-oriented network flow problem (Ford / Fulkerson 1956, Atamtürk 2007) see Figure 1.(2)

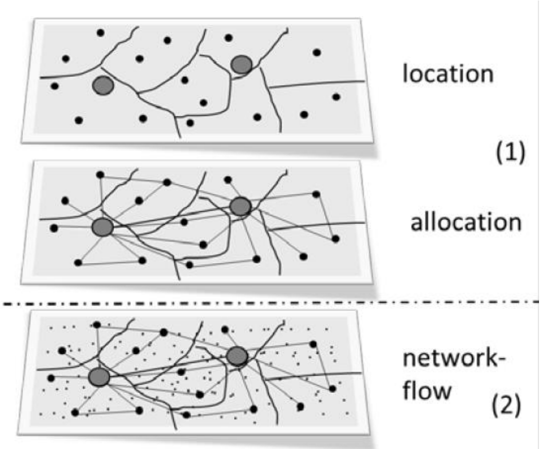

Figure 1: Location/allocation and network flow design

The missing flexibility of location/allocation problems in terms of reacting to stochastic customer demand has to be solved to meet the paradigm of the Physical Internet (Ballot et al. 2014). The basic idea behind the Physical Internet is that logistic objects search on their own for the optimal path through the entire network, until the point of consumption is actually reached. It is therefore essential that nodes and edges of the traditional location/ allocation network are adjusted on a short term basis in order to satisfy the customer needs optimally (e.g. in term of costs). This leads to an expansion on existing modeling approaches of nodes, edges and flows in a logistic network. This approach has to combine the following problems:

- Location: What location of facilities or warehouses is chosen?

- Allocation: Which transport mode is used on which edges of the network? Are new edges necessary?
- Stochasticity: Volatility of customer demand has to be implemented into the location allocation problem formulation.

3. Model description

The based model description is presented in Figure 2. The real data of an enterprise is saved into the database of the generic data model. Based on this generic data model, the network flow model is generated and can be evaluated according to key figures such as transport costs, handling costs and holding costs. A heuristic optimizer was chosen. In this case it was the HeuristicLab framework, which, optimizes the location/ allocation problem and its parameter according to transport costs, handling costs and holding costs. HeuristicLab is an open-source optimization software providing a generic interface, where arbitrary simulation tools can be integrated enabling algorithm analysis, parameter tuning and experiment design (Wagner et al. 2014). This procedure allows the evaluation of different scenarios.

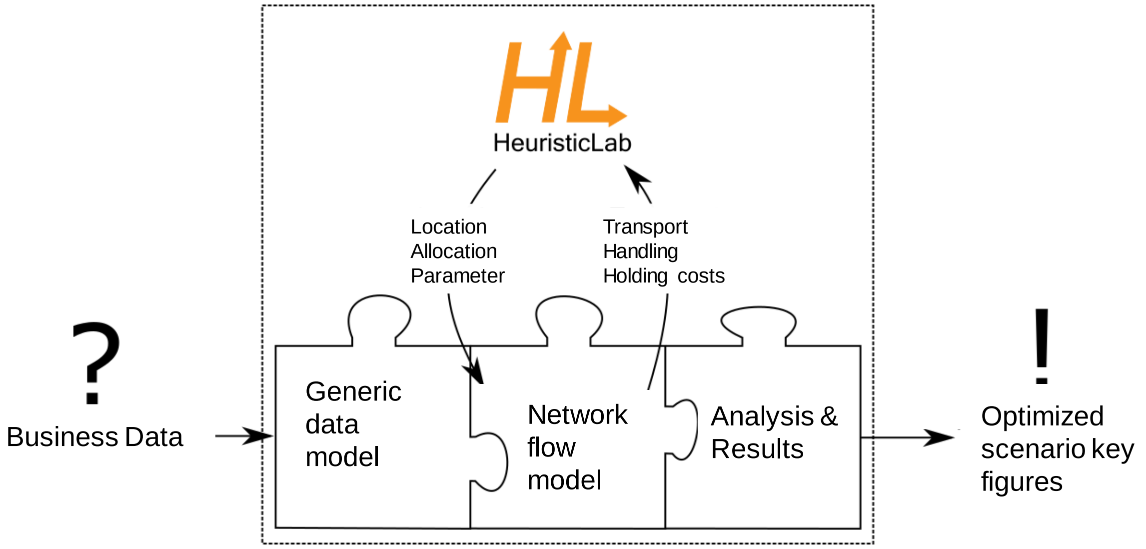

Figure 2. Framework

Both simulation and optimization are enabled access to the data by the use of Google Protocols Buffers. Google Protocols Buffers allows a fast and memory efficient transmission and storage of data. Moreover, these protocols are program language- and platform independent. The data model as well as an importer and exporter have been implemented in HeuristicLab as plugins. The developed plugin allows further applications of network analysis and design.

The proposed generic data model (see Figure 3) includes all above described aspects of Physical Internet. A company can have one or more facilities. These facilities exist in different locations which can produce and/ or store items. Based on a given material flow of real data, jobs are generated and transported according to their routings defined in the table route. Such a job can consists of one or more different jobs executed in the corresponding location.

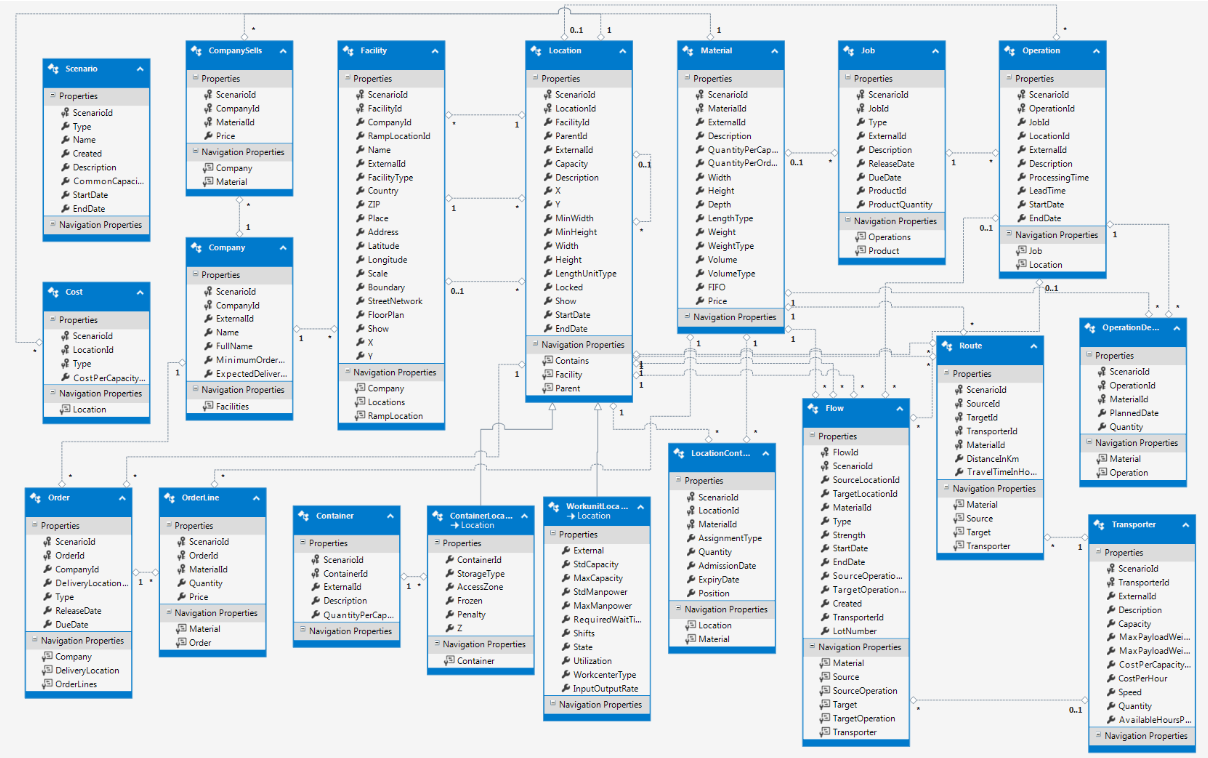

Figure 3. Generic model

Based on the generic database, a network flow model for a given arbitrary scenario has been developed to calculate for the amount of products needed each point in time in the nodes, whereby inventory-, handling- and transportation costs are minimized. As restrictions, all demands have to be satisfied and the capacities available have not been exceeded. The network flow model has been implemented as a mixed integer linear program in IBM Ilog CPLEX as a plugin for HeuristicLab to have direct access to the solver. Moreover, the implementation includes an analysis of utilization for inventories and capacities and the visualization of the calculated material flow.

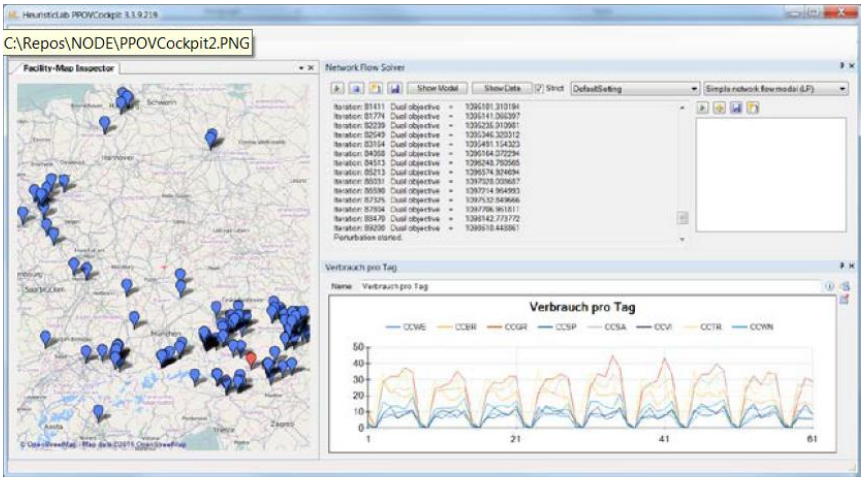

Figure 4. Case study for verification of the network flow model

4. Real case

As result, a real case with 8259 products, 8 warehouses and 210 suppliers is used to verify the developed network flow model. In the first step, the optimal transportation costs are measured and alternative location/ allocation scenarios have been developed as illustrated in Figure 4.

Since the model has been implemented in HeuristicLab, all nodes and edges can be investigated according to their key figures as demonstrated in Figure 5. At this point in time of the project, the results are verified by the domain owner.

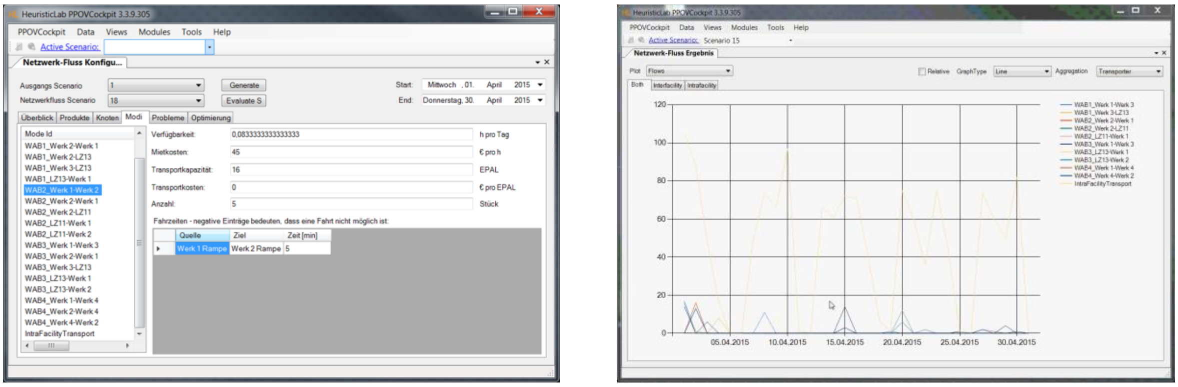

Figure 5. Results

5. Summary

A generic model for analyzing and optimizing location/ allocation problems for value networks (supply chain) has been set up. The model is being verified by a real case. In further research, more real test cases have to be applied in various industries in order to verify the developed model.

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