Cross-Company Logistic Models for Regional Pooling of Transports - a Simulation Approach

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Abstract. Business networking strategies and especially cooperation in logistics is gaining momentum for individual companies in order to survive in competitive markets. As regional transport bundling is a powerful approach to optimize cost structures, this publication deals with the conceptual design and evaluation of cross-company logistics models. For this purpose, a simulation and evaluation model is presented that supports the development of new logistics concepts. Therefore models for the calculation of emissions, costs and logistics competitiveness have to be created and combined to holistically validate and evaluate the new approach. This combination between the three different target values distinguishes the developed model from already published methods. Based on the sustainable approach, potentials for optimization in the areas emissions, costs, and logistic competitiveness can be detected and new sustainable and energy efficient logistics models can be designed.

Keywords: Logistic Concepts, Cross-Company, Simulation Model

1 Introduction

In the last few years many car manufacturers and component suppliers have set up new production sites in or moved existing locations to the Automotive Region Eastern Europe not just to take advantage of the emerging market but also because of the low wage costs [1, 2]. These new production sites, which were established partly with the intention to transfer operations from existing Western European facilities or in order to provide a necessary growth of capacity, supplier and customer structures of the parent plants, were often just assumed. Approximately two thirds of suppliers as well as customers of Eastern European Tier 1 suppliers are still situated in Western Europe [3]. The trend towards relocation has shown that the exchange of goods leads to new demands and challenges for transportation and logistics [4].
At an economic level, one of the main areas of focus for logistics in this context is how to plan and manage transport capacities to cope with the transport flows and the related planning and management of logistics networks for goods, services and information [5]. Particularly transit countries like Austria suffer from increased traffic volumes and constantly rising environmental and infrastructural burden. Further, rising labor costs in Eastern Europe make it necessary to focus on efficient logistics processes. Business networking strategies and especially cross-company co-operation is one of the key factors to improve in production issues as well as in logistics and hence to survive in competitive markets [1, 6]. Therefore a new simulation and evaluation model, which supports the development and evaluation of new logistics concepts, was developed.

2 Cross-Company Logistic Models

The currently applied logistics processes, especially for the specific needs of individual enterprises do not appear optimal from a holistic point of view [7, 8]. Deficits might emerge from direct transport running far beyond capacity, use of small transport carriers, less-than container load with long running times or multiple handling steps as well as bad transportation tariffs due to small quantities. High stocks and capital tied up are results of this inefficiency. Since many companies have a similar source-target-behavior the potential of cross-company bundling to optimize transport efficiency is high.

2.1 Existing Consolidation Approaches

The relevant literature in the field of logistics and operations research knows only very few approaches for planning transportation networks which include the consolidation of transport flows from multiple shippers. Although operations research has been used for almost all types of typical decision situations in intermodal transportation planning, the number of studies carried out for each problem is still very limited and mainly at operational level [9].

A basic approach to evaluate multiple consolidation strategies is proposed by Janic et al. [10] by employing multi-criteria methods and combining them in their Simple Additive Weighting (SAW) method. By doing so they evaluate 23 existing consolidation networks for favorable characteristics. In the case of rail transport they found out that the optimality of a rail consolidation network depends on its number of nodes as well as interconnecting routes and frequency.

Trip and Bontekoning [11] describe an approach for bundling small freight flows into a multimodal transportation network. The theoretical considerations are then illustrated by applying it to an intermodal terminal in the Netherlands.

Another approach proposed by Jourquin et al. [12] is built upon a geographic information system (GIS) which represents the modeling environment for transport bundling activities. Within this environment the user can map different bundling scenarios, whereupon these are evaluated by simulation for their optimality according
to given criteria. The authors present a proof of concept by applying it to a trans-
European transportation network.

Another direction of research is the optimization of traffic schedules as proposed
for example by Newman and Yano [13]. They present a mathematical formulation for
a train scheduling problem in centralized and decentralized environments. Their target
function consists of minimizing “operating costs, including a fixed charge for each
train, variable transportation and handling costs for each container and yard storage
costs, while meeting on-time delivery requirements” [13].

Another scheduling-based approach is presented by Mocca et al. [14]. They
assume that a network can consist of a mix of scheduled and flexible-
time transportation services. Upon this they propose a modeling concept based on digraphs
to map possible network structures. Column generation algorithms are applied
to these models in order to identify optimal scenarios.

A recent approach for planning multimodal transports of hazardous materials based
on lead-times is proposed by Verma and Verter [15]. The paper describes a bi-
objective optimization model to plan and manage intermodal shipments.

As this brief literature review shows, most existing approaches resort to limiting
the search for optimal scenarios to certain dimensions like lead-times or train
schedules. As this reduces the flexibility of possible transport bundling
methodologies, the need for optimization techniques which provide more degrees of
freedom exists. One possible approach is using discrete-event simulation techniques.
As Macharis et al. state, “simulation models offer the possibility to incorporate more
realistic details into the model” [16]. However, one of the main limitations of
simulation techniques is that they are not able to generate candidate scenarios for
optimal transport bundling strategies [17]. Therefore the definition of optimal
scenarios is one of the main challenges when developing logistics models.

2.2 Logistic Networks and consolidation of shipments

There are various approaches for cross-company logistics models that conform to the
general network model of logistics. These models represent networks transporting
rights, goods, finance and information where spatial, quantitative, informational and
temporal differences as well as company boundaries are crossed [18].

The basic structure of transportation links can be represented either as direct
connection in its simplest form or as a multi-stage system with preliminary leg, main
leg and subsequent leg with transshipment terminals where the network nodes serve
as consolidation terminals. The mixture of logistics systems made up from the given
basic structures is decided in the logistical network structure. The processes are
designed when the logistical capacities are superimposed on this.

As described initially, optimization of transports for individual businesses does not
appear ideal; therefore companies can align with partners to a logistical co-operation
and bundle transport volumes. Bundling (source-, target-point or transport bundling),
also referred to as consolidation, happens when transport volumes are combined to
form larger transport batches in order to allow more efficient and more frequent
shipping by concentrating large flows onto relatively few links between terminals.
The starting points for the scenarios for transport bundling are the individual
parameters of the logistical network structure. With regard to the network structure the three main forms of bundling are (1) source-point bundling, (2) target-point bundling and (3) transport bundling.

Transport bundling between two transshipment points on the main leg can raise high potentials due to low transport costs and efficient use of transport capacities [9]. Overall every bundling type must meet the requirements of savings through consolidation of synergy effects to cover higher transport costs, operation costs of handling points or longer distances of time frames in comparison with direct relations.

The goal to reduce costs, while keeping logistics quality at the same level or even raising the service level, is the main focus when designing the logistics network. Thus an iterative method is needed to evaluate the impacts of modifications in logistics models regarding ecology, economy or logistic competitiveness.

Transport bundling or cross-company logistics networks are originally based on the idea of good distribution in urban centers. The different approaches can be summed up with the term city logistics [19]. Other known developments of transport bundling of different suppliers are area contract freight forwarders, bundling and delivering goods for one plant conjointly. Collaborative approaches and the logistics models in this case are mainly based on the following premises:

- Identification of route sections where transport volumes can be handled with efficient transport carriers
- Availability of adequate partner for transport bundling on route sections (legs)
- Possibility of individual businesses to efficient usage of carriers
- Distance from source to target of possible nodes considering impacts of variance from ideal path
- Prioritization from transport volumes given limited capacities of one carrier in the main run as a result of different impacts on target categories
- Possibility to change transport frequency

3 Developing a Holistic Simulation and Evaluation Model

Transport processes are subject to random fluctuations whose characteristics can influence the subsequent processes. The correlations are not linear and can have volatile effects on costs, environmental impact and transport times. The reciprocal effects can be manifold and make it more difficult to create a mathematical model and its analytical solution.

By describing the behavior and the possibility of providing process cycle time fluctuations using distribution functions, so-called confidence intervals can be determined through a number of replications, which allow a prediction to be made as to the bandwidths where the target dimensions are likely to be within a given level of probability.
3.1 Evaluation model for described logistics models

The starting point for the design and evaluation of new logistics models was the current state of the art with regard to known logistics models and structures that involve the organization of transport according to ecological principles. The control variables required to achieve the objectives are:

- Traffic avoidance,
- Bundling of good flows,
- Switching freight transport to other means of transport.

It is also necessary in the long term to validate the results of the models’ conceptual design. This should be performed in accordance with the main target dimensions. The ecological evaluation is a result of determining the impact of CO\(_2\) and NO\(_x\) as well as an estimation of the amount of particles released into the environment. It is in particular the intermodality aimed for in the models that plays an important role in the evaluation of this target dimension. The emission levels are mainly dependent on the journey, i.e. distance covered by the predefined journey profile and on the allocated transport resource. Fuel consumption is also an input value for part of the transport costs in the economic evaluation. The total costs are the sum of the transport, transshipment and differential inventory costs. With transport costs it is important that the model is based on the actual costs incurred, i.e. the overhead costs, road charges, customs clearance and wage costs and not on the transport tariffs charged by shipping companies. The road charges are particularly difficult to determine due to the differing systems in the individual countries and play a considerable role in fixing the route. The third criterion, logistic competitiveness, is made up of the ability to deliver (a measure of the extent to which the company can guarantee the logistical service requested by the customer - short delivery times compared to the competition are especially important for high ability to deliver) and delivery reliability (delivery reliability rates the service provision of the logistics process - it indicates the proportion of the complete and punctual deliveries compared to all delivery orders) [20].

The evaluation models are populated with data from actual surveys or based in part on assumptions and research findings and then analyzed, or are the result of simulated models. In this case, different scenarios can be evaluated and compared based on the target criteria. Due to the conflicting target dimensions, the results should be viewed as compromise proposals that can be regarded as the basis for decisions. Beyond that, the identified parameters are often afflicted with uncertainty.

3.2 Simulation Model

In order to prevent the logistic planners, who are usually well trained in their respective system domain, from dealing with the simulation expertise itself, it was aimed to develop an instrument that lets him answer upcoming questions without specific simulation know-how in an accessible amount of time. Therefore, the base of the simulation model is formed by individual logistical building modules (factory, transshipment centre etc.) that can be combined with one another to represent any
desired logistics concept. These building modules were created in the simulation environment Flexsim® based on the transport flows analyzed and then stored in a library. The generation of the simulation model is therefore effected automatically.

Structural, procedural and resource-related data are required in order to model with the simulation system. By modeling with building modules, it is possible to describe both the structure and the behavior of individual resources independently and their interaction with other building classes. This inherent knowledge contained in the individual building classes is used and extended by configuring the building classes to form an overall model. The individual phases starting with the acquisition and preparation of data up to the analysis of the scenarios pass through the different stages as shown in the following figure:

![Simulation and evaluation model for processed data](image)

**Fig. 1.** States of the simulation and evaluation model for processed data [8]

### 4 Exemplary Demonstration and Forms of Implementation for Cross-Company Logistic Models for Regional Pooling

The application of the modeling approach to a Romanian automotive cluster will be presented as the result of the research project Trans Austria, a research project funded by the Federal Ministry for Transport, Innovation and Technology (BMVIT) as well as the Austrian Research Promotion Agency (FFG). Focusing on 7 automotive companies volumes of outgoing transports were analyzed. Starting from the current state of individual transports, different scenarios were defined. The scenarios are aimed at cost reduction and sustainability in using modes of transport for high volumes like rail traffic.

![Scenario maps](image)

**Fig. 2.** Scenarios 1 and 2 of transport bundling in Timis Region.
Figure 2 shows two out of the defined scenarios of transport bundling for the Timis Region. Scenarios 1 using block train with 3 stops and direct transport on the preliminary and subsequent leg not considering locations that cannot profit from consolidation with the block train on the main leg. Scenario 2 limits the block train to one stop and bundles transports further on the on the preliminary as well as on the subsequent leg, after leaving the train to their final destinations. Destinations not considered in the main leg bundling where consolidated as well in scenario 2. By shifting the main leg to railway and optimizing the collection and distribution of goods from and to transshipment points logistic costs could be reduced by 15 % in the given case. The ecological impact in reduction of CO₂ emissions by 40 %, cutting fuel consumption in half, shows the success in more than one target dimension. The main deficit of the models is overcoming the doubled lead time coming from the ceteris paribus inspection of transports. In addition to the simulation and evaluation of scenarios a sensitivity analysis was executed to cover the ecological and economical results. The model indicated shows full functionality even with fluctuation of volumes and prices.

For the implementation of cross-company logistic models for regional bundling especially the organization model behind is essential for success. That is why transport agents, who are working as neutral coordinators between the co-operating companies, try to implement the concepts. The main tasks for the agents are consolidating the individual transport loads and cost rates of the network and to distribute loads to order pools. The process starts with data consolidation, filtering data, identifying potentials and creating pools to test the market. Neutral coordinators see the main benefits of the model for suppliers in price and flexibility through more volume and no direct co-operations to every single company needed. Therefore the quality and service with neutral agents can be increased. Especially the confidence of firms in train as a mode of transport, the stability of chain and the flexibility of logistical chain and full transport loads are the main challenges in the implementation.

The next level, which is still to be defined, will be the operational connection between companies (delivery dates, packing etc.) to increase transport efficiency even more.

5 Concluding Remarks

This paper visualized models to simulate and evaluate potentials of regional transport bundling for cross-company logistic networks to identify those potentials given a specific case. The empirical analysis showed the great complexity of the problem that was built in a simulation framework and therefore the challenge for possible implementations which constitute further research developments. Optimization of the given set of problems would be a possible expansion keeping in mind the time and cost needed to set up the base and ensuring the transferability of an optimization model. Also the integration of transport planning parameters in production planning and thus combining horizontal and vertical collaboration in the supply chain implies further research.
References