# Spatial Decision Support for Wood Supply Chain Optimization – Modelling Issues

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## Abstract

Wood Supply Chain operations planning is a complex task and now mostly done by individuals. Traditionally this process has some shortcomings that limit the overall performance. The Wood Supply Chain can be seen as a semi-structured decision problem and thus can be supported by Spatial Decision Support Systems. Fundamental for a SDSS is the modelling of the processes that shall be supported. An ERD shows the main stakeholders and gives insight in the underlying database structure. Formulating a Vehicle Routing Problem that solves the questions that should be answered by the SDSS helps to understand the process in detail. Applying Rolling Schedule approaches allows the system to react to dynamic situations and to find optima under uncertain conditions where searching for a global optimum is not recommended.

## 1 Wood Supply Chain: explanation, characteristics and traditional shortcomings

The term Wood Supply Chain comprises all actions starting from the production of timber in the forest until the final product reaches the customer. Thus, there is a strong linkage between customers, suppliers and shippers within forest industry, which requires a continuous flow of information. The information to be shared in the Supply Chain is complex, voluminous and spatial in its nature. The communication between stakeholders is usually not standardized, due to a number of media used to transmit the information. Consequently several media disruptions occur which are documented in BODELSCHWINGH, BAUER & LONGO (2003). Moreover uncoordinated logistic operations are very likely, due to a decision process that is hardly supported by any information system.

The traditional information flow in the Wood Supply Chain is shown in Fig. 2. During the production and transportation process of timber a number of media disruptions within the information path may occur. Especially in regions with very small forest enterprises, where only very small quantities of timber are produced and transported, a centralized optimization of haulage trucks can increase efficiency and rentability which was pointed out in GRONALT et al. (2005).

Modern Information Systems can help to optimize the information flow through all stages of the Supply Chain, but their usage in this field is very rare. Due to the problem's complexity, human knowledge has to play an important role and an Information System can only assist in finding an optimal solution.

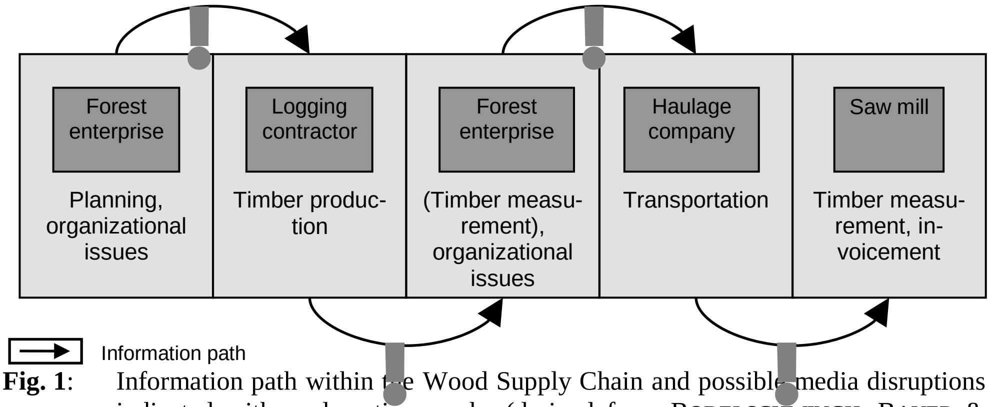


**Fig. 1**: Information path within the Wood Supply Chain and possible media disruptions indicated with exclamation marks (derived from BODELSCHWINGH, BAUER & LONGO (2003)).

## 2 Spatial Decision Support Systems (SDSS) in the context of Wood Supply Chain Optimization

According to MALCZEWSKI (1999) a SDSS is a system that supports the user in solving a semi-structured decision problem. Generally speaking a SDSS consists of a Database, a Database Management System (RDBMS), a Model Base for storing relevant mathematical models, a Model Base Management System and a Dialog Generation and Management System that ensures the communication between the user and the system itself (MALCZEWSKI 1999, 1997).

Concerning the application of SDSS in the environment of the Wood Supply Chain we are going to develop a prototype information platform that helps in avoiding uncoordinated logistic operations and media disruptions. Thus, every stakeholder has access to (near) real-time data, and can pass on relevant information.

To optimize the Wood Supply Chain we focus on the transportation process. There are four basic questions that have to be managed by the SDSS:

- WHAT should be transported? We focus on the quantity and the specific sort of timber (e.g. roundwood vs. pulpwood) that is hauled.
- WHO should transport? Which truck is responsible for the transportation process.
- WHEN should it be transported? Due to a dynamic demand of the saw mills and papermills, a schedule ensures the fulfillment of the requested timber.

- WHERE TO? In order to gain the most profit or to maintain the least ecological impact the timber should only be transported to a specific saw mill/papermill. In addition the fulfillment of the demanded quantity has to be guaranteed.

## 3 Modelling and Optimizing the Wood Supply Chain

As described above, a RDBMS in combination with mathematical models serves as basis for any SDSS. Entity Relationship Modelling (CHEN 1976; IEEE 1998) identifies the relevant entities, attributes and relations, that are outlined in the corresponding Entity Relationship Diagram (ERD) using IDEF1X notation (IEEE 1998). Fig 2 shows the ERD that was developed so far. Analyzing the Wood Supply Chain results in four main "entities": a) Saw Mills: where timber is demanded b) Forest Enterprises: where timber is produced c) Haulage companies and corresponding trucks d) Transport: serves as connector between timber demand and timber supply which are represented as nodes or vertices. The ERD in Fig. 2 shows two transport entities, due to the fact that planned and completed transports are stored separately.

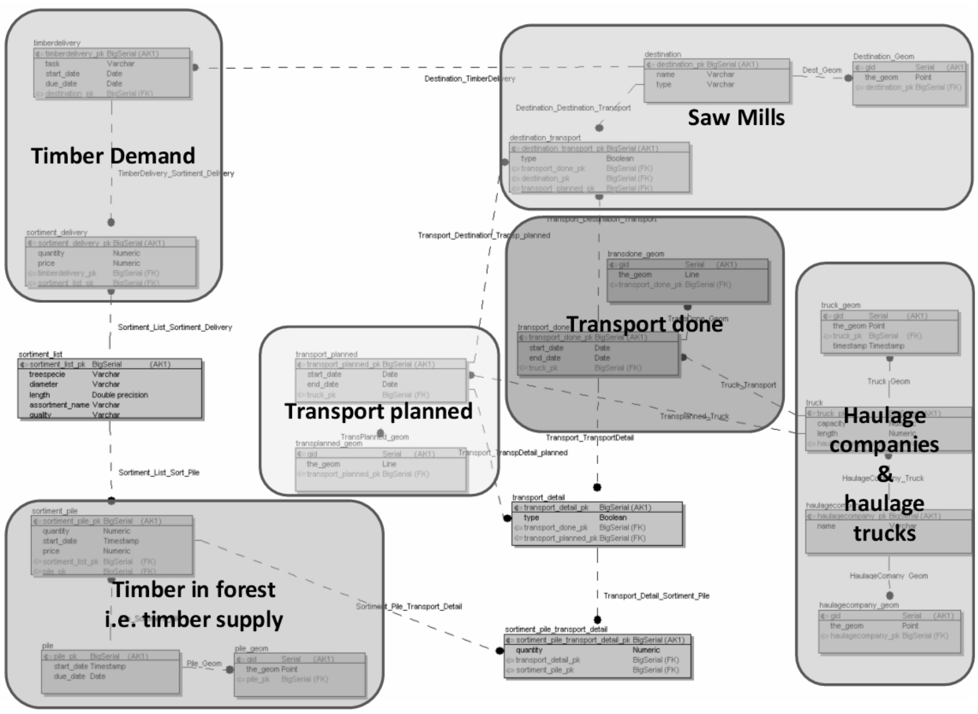


**Fig. 2**: ERD of the RDMS in IDEF1X notation.

The mathematical modelling, i.e. an optimization problem, uses a standard Vehicle Routing Problem (VRP) (e.g. DORRONSORO 2007, BRAMEL & SIMCHI-LEVI. 1997, TOTH & VIGO

2002, EISELT & SANDBLOM 2000) as basis for further investigation. Two variants of the VRP, namely the VRP with Pickup and Delivery (VRPPD) and the VRP with Time Windows (VRPTW) are used to model the Wood Supply Chain accordingly. The VRP results in an optimization problem that can be described as follows:

Objective:

- maximize profit, i.e. reduce transport costs while increasing the sales revenues

Subject to:

- limited load capacity per truck
- limited number of trucks
- time window constraint for each pickup node – all timber located at a pickup node must be hauled within the given time window
- time window constraint for each delivery node: the demanded timber must be delivered within the given time window
- limit timber delivery to saw mills: do not deliver more than demanded
- limit working time of each truck due to legal regulations

In order to reduce the ecological impact of the transportation process itself, the objective function and the weighting of the edges of the underlying road network have to be altered. Thus the objective function has to be defined in the following way: minize emissions of haulage trucks. An advanced model may include a weighting between ecological and economical objectives.

The resulting VRP model has to be optimized in order to answer the questions listed above. We propose three solution techniques: a) Heuristic: Local Search b) Metaheuristic: Tabu Search c) Exact technique: Branch and Bound. Local Search and Tabu Search are approximation algorithms and do not give any information on quality or optimality of the solution found, but are very efficient. Branch and Bound computes until optimality is reached. Although it utilizes a mass discarding of fruitless solutions, the computational complexity is high.

In order to cope with the dynamic situation present in the Wood Supply Chain, e.g. weather making roads impassable or uncertain timber demand, it is not suitable to search for global optima. Rolling Schedule approaches (WAGNER & WHITHIN 1958, TENG, ONG & HUANG 2006, SPITTER 2005) are a technique to model under uncertain and dynamic conditions. In the case of Wood Supply Chain optimization, future conditions are very likely to change and a prognosis of e.g. weather is very difficult. Thus Rolling Schedule approaches divide the time into discrete time periods. By considering a plannig horizon that comprises several time periods we can cope with the uncertain situation. We optimize the VRP mentioned above only within the planning horizon where we are dealing with limited uncertainty. When the first time period of the rolling horizon is over, the horizon is moved forward by one period (see Figure 3) and the optimization process is started again.

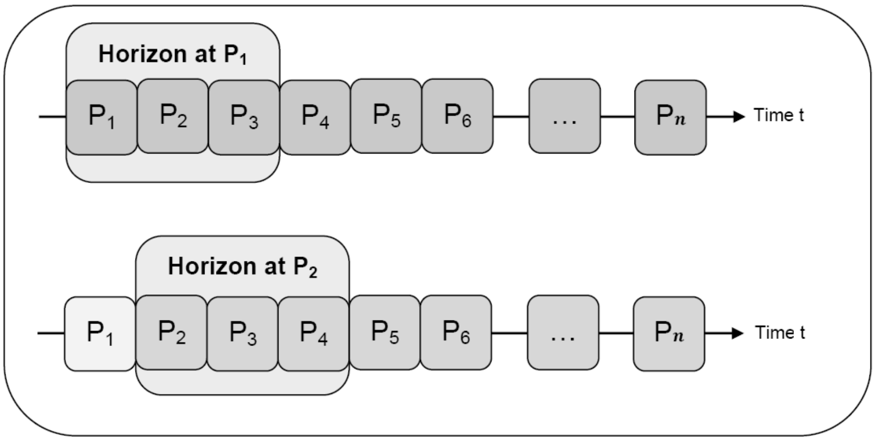


**Fig. 3**: Rolling Schedule approach illustration: Time is divided into discrete time slices $P_1$, ... , $P_n$. A rolling horizon defines the optimization environment concerning the temporal dimension. After $P_1$ is over, the rolling horizon is moved forward by one period.

## 4 Summary and further research work

This paper proposes an idea to support the Wood Supply Chain operations planning in an interdisciplinary manner building upon GIScience and Operations Research. Of basic interest is an ERD for modelling the spatial database of the SDSS. Modelling and formulating the process of Wood Supply Chain operations planning as a Mixed Integer Program helps to understand the process in detail and to to solve the optimization problem using the techniques mentioned. A detailed analysis and comparsion of the optimization techniques is still work in progress. Integrating a hierarchical wayfinding model (CAR, TAYLOR & BRUNSDON 2001) could certainly improve the routing and optimization process and will be part of further investigations. Integrating the modelling approach in an SDSS may help the practitioner in the forest business. A future reference implementation of the SDSS will prove the concept and is a current working item.

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