

Logistics optimization of the production chain in forestry by means of simulation software

by Anne-Katrin Bruchner, 2002

Abstract

Simulation software is a common tool in several different industrial branches for optimizing internal production and logistics. It is designed for analysing, planning and controlling material handling systems. An evaluation by multiple goal analysis showed that simulation software could be usable as a tool for the operational planning and various process calculations in the forest sector. It can assist to identify the most efficient machine combinations for wood production. The applicability of the software will be tested by building and simulating a forestry model in the programme. The current research focuses on one forest estate located in Southern Germany. Harvesting operations and primary transport will be modelled and analysed due to real world data. Two different models are generated and studied in the simulation. After the implementation of the basic data it is possible to build different operational scenarios which show advantages and disadvantages of ecological, economical and technical impacts of the different logging processes modelled. The objectives of the studies are to investigate the applicability of discrete-event simulation for modelling harvesting and transport systems and to reveal the problems of adaption in forestry at the operational level.

Keywords: simulation, modelling, wood supply chain, logistics, forest operations, harvesting, transport
Introduction

The annual cut in the German forest industry amounts to 40 Mio cbm. Two thirds of the harvested roundwood are delivered to saw mills. Enterprises in the forest sector today have to compete in a global timber market. To fulfill the requirements of their customers and to meet international timber prices it is necessary to reduce operation and transport costs in the timber harvesting process.

Improved organisation and planning of harvesting operations in forestry have been identified as a means of optimizing the disposition of log assortments for timber and paper markets.

The saw mills as well as the pulp and paper industry require roundwood from forest enterprises in requested quantity and high quality. The challenge for forestry today, is to maintain a market orientated timber supply and to become a proactive industry instead of a reactive one. Harvesting operations are still mostly planned due to silvicultural regimes but in the future, with growing investments into machines, economical aspects are going to be even more important for the positioning of an enterprise in a global timber market. Low operational costs and high technical productivity of the machinery will become increasingly important for forest operations. An improvement of the integral logistics management can only be achieved by taking a close look at all elements of the production chain.

The main task of forest logistics in Germany is to manage the material and information flow in all segments of the wood supply chain from felling to mill. In order to be able to respond to the industrial dynamics it is important for the forest enterprises to know precisely their production layout and stand inventory at any time. Planning processes within the operational system that are based on an up-to-date inventory of the raw material could be optimized by using supporting tools like simulation software.
Modelling an operational system in forestry

In German forestry three main partners are responsible for the material and information flow in the wood supply chain:

- forest enterprise
- long distance haulage company
- sawmill / papermill

These companies mainly operate independently from each other. A lack of information and disturbances in the communication cause high costs and a deficiency in the customer service throughout the production. The most cost intensive parts in the wood supply chain are the harvesting operations and the primary transport. Simulation software makes processes more transparent, unveiles problems in the operation system and thus helps to lower costs.

Figure 1. Partners of the wood supply chain in Germany (Warkotsch & Ziesak, 1998)
After comparing forestry systems to other industrial branches not only similar structures can be identified but also a few important differences. In forestry the operational system including harvesting and primary extraction is performed in an environment that is characterized as material depot and production area all in one. In other industrial plants these functional areas are separated. That means that in forestry the production takes place in relatively large „store houses“. After production steps like harvesting operations and skidding, the wood assortments get stacked in a depot ready to be loaded on trucks and to be transported to the mill.

![Figure 2. Production environment for harvesting operations (Bruchner, 2000)](image)

Simulation runs of modelled systems are used for analysing large and complex real-world situations that cannot be solved by analytic operations research methods because of various interactions between the system components. A large number of variables, parameters and also functions can be handled. An advantage of modelling is that it does not disturb the real system, and various decision-making scenarios can be tested without interfering. The system can be run in a short period of time because of the possibility of compressing time in computer simulations. Therefore, simulated data are much cheaper to collect than similar data from the real-world system. A computer based simulation model describes the system and its individual components whose behaviour can be predicted. This feature allows a study of the interaction between individual activities in the system. Contrary to analytic models, each simulation model is unique: It is tailored for a specific problem to answer specific questions. Its solutions are usually not transferable to other decision making situations (Render & Stair 1992).
In comparison to other industries timber production is part of an extreme complex system. It is performed in a sensitive environment and can be disturbed by various chaotic impacts due to climatic effects, e.g. storms. A forest enterprise in Germany has to deal with the management of a „factory“ area with an average size of about 10.000ha and has special production conditions such as inhomogenous stands and seasonal changing weather conditions. Standard simulation software has to be adapted to these special requirements in forestry.

**The Purpose of using Simulation software for production systems**

Simulation software is a common tool in several different industrial branches for optimizing internal production and logistics and is designed for analysing, planning and controlling material handling systems. The basis is representing the production area close to reality and having actual inventory data about the material, the machinery, road and stand conditions. In our research simulation software is used as a tool to facilitate and rationalise productivity and cost calculations. Furthermore it is a supporting tool for strategic and tactical planning of forest operations. As a result problems and shortcomings in the production process can be located and logging operations can be optimized. Transport distances can be reduced as well as lead time. In the end a smooth flow of the material and the products can be reached. Simulation models include non-linear functions, random variables, independencies of system elements and behaviour of dynamic systems. Model components can be simulated in details as well as machine interactions. The effects of these interactions on the system can be quantified. The waiting times and delays caused by other components in the system are illustrated and their effects on logging costs and productivity can be estimated. Simulation can be used for an interactive optimization of the system: various alternatives are tested and decision variables are evaluated (Asikainen, 1995).

For modelling different timber harvesting scenarios it is necessary to have basic information on stand characteristics, logging roads and machinery data.
The following parameters are required for an implementation of simulation software in forestry:

- topographical information: digital forest maps with logging roads and extraction lines, digital 3D models for slope information
- information about the "storehouse capacity": number of trees, distribution of tree species, classification of the stands according to alternatives of silvicultural management
- raw material: diameter at breast height (dbh), length and volume of each single tree
- produced log assortments: tree species, short wood/long wood, quality/dimension
- information about the production: characteristics of alternative silvicultural treatment (cutting, time of cutting, produced assortments)
- information about harvesting and transport operations: data on productivity and costs

Research Methodology and Applied Simulation Technique

The first step in our research study was to evaluate simulation software which could be adapted to complex systems such as the production chain in forestry. Eight different software packages were compared and evaluated in a multiple goal analysis by means of a catalogue of criteria containing several specific forest requirements. Requirements on the production layout, the manufacturing process and the products were tested. One of these simulation software packages is now applied. The second step in our research consists of an intensive investigation of the selected product. A simulation is parameter-driven and requires computer language based programming as well as visual interactive programming by means of a manufacturing simulator. Within this discrete simulation a material handling system can be defined with all its physical components in an edit environment in which the logic is also programmed. The simulation can then be run in a simulation environment in which a detailed 3D real-time visualisation of the system is generated.

The development of the forest model is divided into five phases:

1. Definition of the problem the model should solve
2. Construction of the model
3. Simulation runs
4. Verification and validation of the model

Subsequently an implementation of the results in the real-world system is intended.

The simulation of the current research focuses on one forest estate located in Southern Germany. The stand data are results of detailed research work of the Chair of Yield Science and the Chair of Silviculture of the Technical University of Munich and are provided for the model. At the beginning of the simulation, harvesting operations will be modelled and analysed on stand level. The number and combinations of different operations can be extended with time. After the implementation of these basics it is possible to build different operational scenarios. The user of the software can call up statistics for every single step of each operation at any time of the running simulation.

Modelling forest operations

Two different models are generated in the simulation software:

- pure spruce (Picea abies) stand
  average dbh 33.1 cm, average height 32.4 m
- mixed spruce/beech stand (Picea abies / Fagus sylvatica)
  Picea: average dbh 32.7 cm, average height 32.3 m
  Fagus: average dbh s 31.9 cm, average height 29.5 m

In each model two operation combinations are calculated:

Combination 1: Felling by harvester, skidding by forwarder
Combination 2: Felling by chainsaw operator, skidding by forwarder
Results of the Application of Simulation Software in Forestry

In a multiple goal analysis eight different software packages were compared and evaluated. One of the simulation software packages is now transferred into forestry. The applicability of the software will be verified by building and simulating a forestry model based on real-world data into the programme. Most effective and efficient machine combinations for timber production shall be identified and optimized. Simulation statistics give detailed real-time information about the harvesting and transport processes as shown below:

Simulation software allows the following statistical parameters in forestry:

- productive machine hour
- degree of utilization of the growing stock
- costs: staff costs, machine costs, fixed costs, profit contribution
- energy consumption
- total driving distance of the machines (harvester, forwarder) during the operation
- distribution of machines on logging roads and extraction lines
- payload of the machines
The advantages of a computer based simulation model for forest enterprises are:

- optimizing and reducing costs throughout all phases of production
- increasing product quality and improving forecasting of available timber supply quantity
- improve service output for their customers

Conclusion

Industrial simulation software could be a flexible tool for modelling producing components of the supply chain in forestry as well as in the pulp and paper as well as the timber industry. Various simulation programmes are available but only a few of them could be used for such complex systems as in forestry. For modelling different timber harvesting scenarios it is necessary to create a model of a forest enterprise which is representing the production area close to reality and is providing actual inventory data about the material, the machinery, road and stand conditions. The main purpose of it is to have an instrument for planning and controlling of all production processes.

Modelling and simulation can be used for analysing large and complex real-world situations that cannot be solved by analytic operations research methods because of various interactions between the system components. A large number of variables, parameters and also functions can be handled. On the basis of a concrete example in Southern Germany several scenarios will be tested. Based on the calculated data decisions in the planning process of logging operations can be made considering ecological, economical and technical aspects.

Literature


No.1.Oskarshamn/Schweden: Hrsg. Frumerie,G.


The author

Anne-Katrin Bruchner, Technical University of Munich
Department of Forest Work Science and Applied Computer Science
Am Hochanger 13, 85354 Freising, Germany.
e-mail: bruchner@forst.tu-muenchen.de