DEMAND ESTIMATION AND DYNAMIC MODELLING AS TIMBER PRODUCTS INDUSTRY SCM TOOLS

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Abstract: In this paper a new approach to the modelling of a supply chain is presented. The chain is modelled with dynamic elements representing the different parts of the chain. Matlab based simulation tools are used to find different stock and transportation management principles. A link to the economical evaluation of such schemes is presented. A scheme is derived for the management of the whole supply chain from forests to users of sawn timber products is to facilitate the long term development of the supply chain management and the necessary information and communication management tools.

Keywords: Dynamic modelling, forecasts, system theory, simulation, metrics.

1. INTRODUCTION

Management of logistic chains has been mainly done using static models with the target of optimizing the long term balance rather than flexibly reacting in short term fluctuations in demand. This is due to fact that transportation has been easiest to acquire on long term contract basis. Today, market demand of goods fluctuates more and lifecycles of products become shorter. Short term planning of logistic chain becomes more important. Increasing yield expectations of working capital force companies to minimize stocks and shorten delivery times. This is true for shelf-life products. Transportation companies are improving services to satisfy even the short term customer demand by modern IT and flexible transportations. This makes management of supply and demand chains more dynamic than previously and requires dynamic tools for management.

1.1 Background of the Study

The study described in this paper is based on a project where academic research in the field of dynamic modelling of logistics systems has been combined with industrial high volume application of improvements. The participants of the project represent academia and industry. Three research institutes have been involved as well as one transportation company, one company selling the products to the end customers and one company that produces, markets and sells the products. The objectives of the research are to reveal problems with the current operating methods, analyse success in some supply chains as well as create a modular platform for further studies of existing or future logistic chains.

1.2 Related Work

Supply chain is mostly modelled with event based modelling. Chang and Makatsoris (2001) study the requirements for supply chain discrete event simulation modelling. There are studies with different approaches: Petrovic et al. (1999) study supply chain modelling using fuzzy sets as Chen and Tzeng (2000) have a fuzzy multi-objective approach to the supply chain model and Carlsson and Fullér (2000) present a fuzzy approach to the bullwhip effect. They consider a series of companies in a supply chain ordering from its immediate upstream member. Li and O'Brien (1999) use dynamic, objective programming for modelling supply chain efficiency. Minner (2001) aims at modelling complexity in a supply chain. Angerhofer and Angelides (2000) give an overview of recent work on system dynamics modelling in supply chain management. They focus on inventory decision and policy development, time compression, supply chain design and integration, demand amplification and international SCM.

Schönsleben (1998) has studied demand forecasts and forecast methods in supply chain management. He divides forecast methods into history-based and future-based methods. History-based demand forecasts are analytic methods based on consume statistics and can be further divided into mathematical and graphic methods. Future-based demand forecasts use existing information about future demand (offers, confirmed orders in a contracting phase and interviews on customer behaviour). (Schönsleben, 1998)

1.3 Objectives and Contents of the Paper

The objective of the paper is to study demand estimation and dynamic modelling as supply chain management tools for timber products industry. The aim is to find proper metrics for the whole supply chain.

First, the complexity of the business environment and products involved are described, then the main theoretical issues of supply chain modelling are discussed, i.e. dynamic modelling and supply chain metrics. After that, the main results of the project are described: dynamic models for supply chain management, supply chain metrics and demand forecasts.

1.4 Research Methods

Dynamic modelling has been used as a tool to study a typical supply chain for timber products. Modelling has been done with **Matlab Simulink** environment. Matlab is "an integrated technical computing environment that combines numeric computation, graphics and visualization, and a high level programming language". **Simulink** is "an interactive tool for modelling, simulating and analyzing dynamic systems. It allows building graphical block diagrams, simulating dynamic systems, evaluating system performance and refining designs". (MathWorks, Inc.) Simulation results are used for comparing different control methods of a supply chain.

2. BUSINESS ENVIRONMENT

Thorough knowledge of the business environment is a prerequisite for successful modelling. Therefore, the business environment of an industrial wood products company is described. Possible methods for managing business environmental factors are also discussed. These are shown in Fig.1.

Outsourcing is a continuing trend as companies tend to focus on core competence areas. A trend from the customer perspective is that customers demand faster deliveries of products in smaller batches. Moving the interface closer to the actual customer can be done using different approaches, for example Vendor Managed Inventory. Fluctuating raw material supply covers all aspects of timber procurement including factors in taxation, problems in timber harvesting and factors connected with wood imports and political changes in the countries of origin. Long supply-chain can be understood in two different ways. First the actual length and numbers of phases in the chain, secondly in time perspective - as the amount of time used in a typical supply-chain in wood processing industry is rather large.

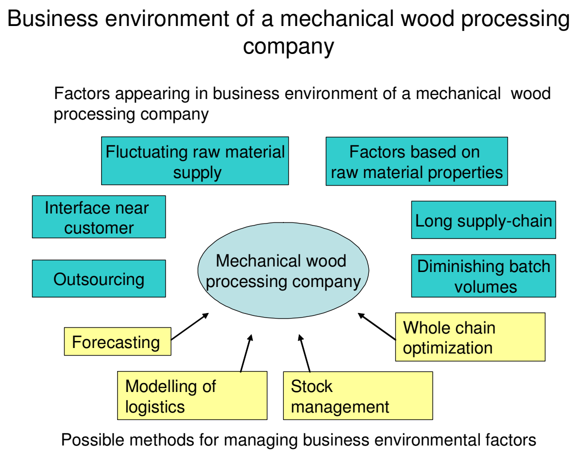
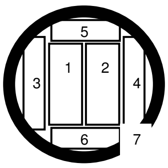


Fig. 1. Business environment of an industrial wood products company.

Possibilities to affect the changes in business environment are modelling, stock management, forecasting and chain optimization. Forecasting can be helpful when faced with the problems rising from the long time perspective of the supply chain. Modelling of logistics delivers a clear picture of the actual state of current level of logistics, making controlling and developing logistical issues easier.

There are some special characteristics of sawn timber products that make the management of their production and logistics different from other products. First of all, their value vs. volume ration is low for the main volume. However, these low value goods have to be combined with the higher value added products in transportation to obtain minimum overall cost. For example, a shipload of timber may consist of 95% (of volume) of sawn timber and 5% of value added goods. This leads to different stocking principles for different products.

In sawn timber production when a single product is desired, many side products result. Also, these side products are sold in the same markets as the main product affecting the pricing of all items. Therefore, it is absolutely necessary to be able to manage the formation of side products. In Fig. 2 the formation of different products from a single log is described. The management of these side products makes the information flow in two directions. Market driven part of the management of main products demanded by the customers has to be tightly combined with the selling and marketing of the side products to the same and other customers.



One main product and possible 8 side products:
1 main product
2 main product dimension, different quality
3 side product, dimension A, quality I
4 side product, dimension A, quality II
5 side product, dimension B, quality III
6 side product, dimension B, quality IV
7 bark
8 sawdust
9 wood chips

Fig. 2. Cutting of a log for a main product and resulting side products.

3. THEORY

3.1 System Dynamics

System dynamics is a computer-aided approach for analysing and solving complex problems. The perspective is based on information feedback and delays to understand the dynamic behaviour of complex physical, biological and social systems. (Angerhofer and Angelides, 2000) It has its origin in control engineering and management (developed from the work of J.W. Forrester). System dynamics has been used for forecasting behaviour of the markets, establishing a structural framework for decision making, challenging industrial assumptions, shortening delivery times, improving customer service quality, and discovering new strategies. System dynamics has been applied to logistics and supply systems by e.g. Towill (1997) and Christopher (1992). (Towill, 1997; Christopher, 1992)

3.2 Supply Chain Metrics

Different measurements for estimating supply-chain performance are produced during this project. These metrics are based on three particular areas of interest in the supply chain, namely speed, assets and service as presented by Haussman. (Haussman, 2002) The need for metrics that concentrate to the whole chain rise from the fact that current metrics measure only the effectiveness of a single chain member. This causes problems as all members tend to optimise their operations without seeing the sometimes massive impact to the whole chain.

	Performance Attribute	Performance Attribute Definition	Level 1 Metric
Customer Facing Attributes	Supply Chain Delivery Reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer.	Delivery Performance
			Fill Rates
			Perfect Order Fulfillment
	Supply Chain Responsiveness	The velocity at which a supply chain provides products to the customer.	Order Fulfillment Lead Times
	Supply Chain Flexibility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Supply Chain Response Time
			Production Flexibility
Internal Facing Attributes	Supply Chain Costs	The costs associated with operating the supply chain.	Cost of Goods Sold
			Total Supply Chain Management Costs
			Value-Added Productivity
			Warranty / Returns Processing Costs
	Supply Chain Asset Management Efficiency	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time
			Inventory Days of Supply
			Asset Turns

Fig. 3. SCOR level 1 process measures. (Business Process Trends, 2003)

This is called partial optimisation, a course of action which should be replaced with a better solution. Metrics can be seen as a powerful way of operating the chain and wrong metrics may cause equally significant problems. Supply Chain Operations Reference model (SCOR) includes suitable metrics for supply-chain measurement as presented in Fig. 3.

3.3 Demand Estimation Theory

There is a clear difference between demand and sales. Every product and service has its own demand in certain time. Factors affecting demand are price, marketing, competitors supply etc. The influence of these factors depends on products' characteristics and market environment. It's obvious that all factors affecting consumer buying behaviour and formation of demand can not found. Sales is a result of simultaneous demand and supply and the effect of supply varies a lot. Some customers may accept long waiting times while the others have to get product straight from stock. Same kind of differences can be found from different products.

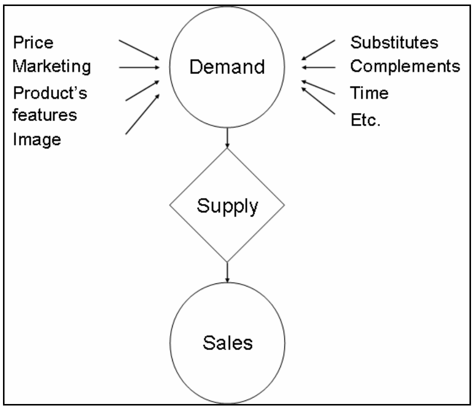


Fig. 4. Factors affecting demand.

Demand forecasting methods can be divided into three groups: time-series models, econometric models and qualitative models (Ballou, 1999). Time-series models are the most commonly used because they are based on the sales history data that is easy to obtain. Econometric models are more complicated and mostly used for demand forecasting i.e. they take into account the factors affecting demand (see Fig. 4). Qualitative models can be used for estimating the demand of new products or for long-term forecasting.

Demand estimations consist of expected value and variance. Expected value estimation is valuable for production management while variance estimation is useful for inventory management. When the delivery reliability of a product is known the stock level needed to satisfy the demand can be defined.

4. RESULTS

4.1 Supply Chain Control

In Fig. 5 the traditional method to control supply chain is presented. In this method the retailer's order information is shared step by step from the sales office to sawmill. In fluctuating demand condition this step by step method causes unnecessary delay and may lead the system instability that might badly impact the ability of the supply chain to satisfy its customer's needs.

One of the major problems of the traditional control method is the unnecessary delay that comes from the step by step feature. The delay can be reduced, for example, by increasing the transparency of the chain. In Fig. 6 a control method with open information sharing is presented. In this method the sales office shares the sales information to both production units. Furthermore, production units share information to each other in order to time production, minimize stocks and shorten the delivery times.

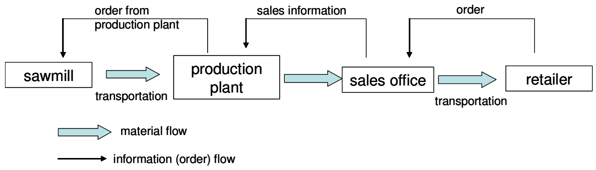


Fig. 5. A traditional method to control supply chain.

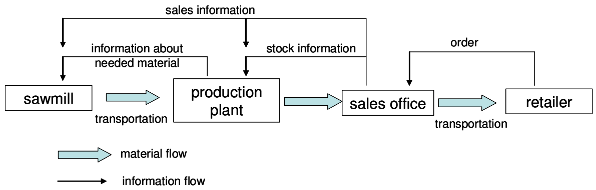


Fig. 6. A control method with open information sharing.

In this project the effect and possibility to use retailer's order information to control directly the supply chain are studied. Moreover, the opportunity to use demand forecasting as a part of control method will be studied. The fundamental idea to use forecasting as a part of control method of the supply chain is presented in Fig. 7.

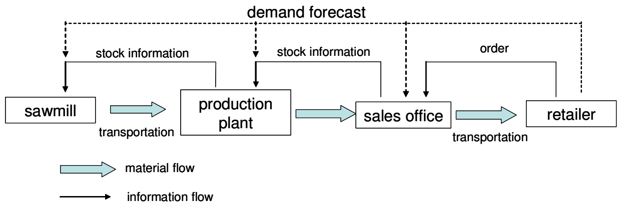


Fig. 7. Demand forecast as a part of the control method of the chain.

Simulations

Simulations have been carried out to compare different control methods. Control methods were compared using the stock values and the following statistics in time period of one year.
- working capital per transferred material to retailer [€ / m^3]
- number of days the stock value in retailer is zero
- the value of material that has been transferred to retailer [m^3]
- average value of material in stocks in the chain [m^3]

Simulation data was collected for three-year period (one year is 300 days) and one simulation period is three years. In Fig. 8 the simulation results of the traditional control method are presented. This figure is divided in two plots. The upper plot describes the retailer's order information to sales office against the shipments to retailer as a function of time. The shipment has taken place when the goods reached the retailer's stock. The lower plot presents the stock values of the sales office and the production plant as a function of time.

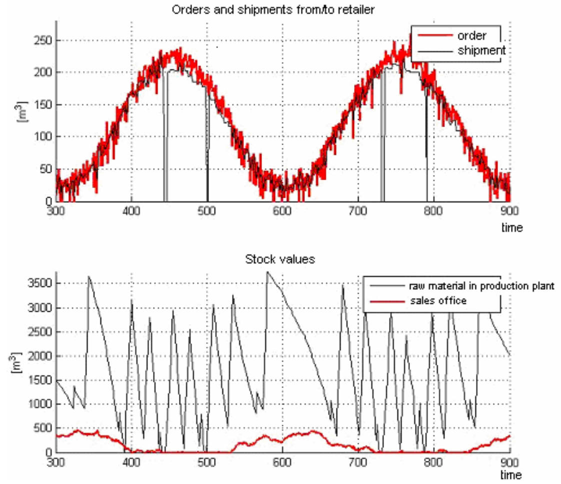


Fig. 8. Simulation results from the traditional control method.

In Fig. 9 the simulation results of the control method an open information sharing are presented. As the results of simulation show (Fig. 9) the raw material stock in the production plant is now behaving nicer and the material flow to the retailer is now more regular than the traditional method. Most of all, no zero days were seen in the retailer's stock. Fig. 10 shows the differences between traditional and transparent control methods. Though the advantages of the transparent method are clear it should be kept in mind that when studying different methods to control supply chain it is not only the information that is important but also the right information should be transferred to the right place.

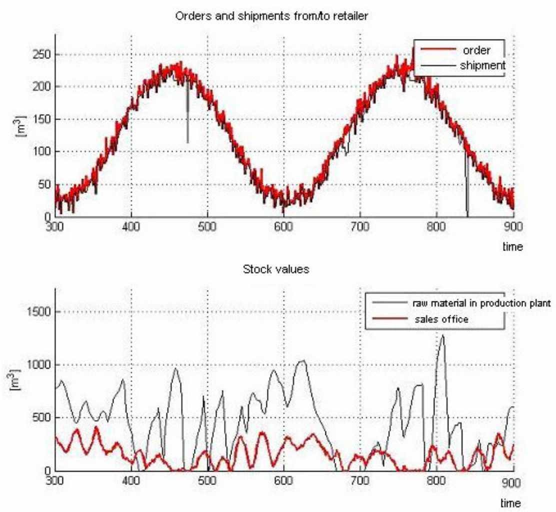


Fig. 9. Simulation results of open information sharing.

Statistics time period one year	control method	
	traditional	transparency
volume of material transferred to retailer	33100 m^3	36300 m^3
average value of material in stocks in chain	1840 m^3	1200 m^3
working capital per transferred material to retailer	224 € / m^3	207 € / m^3
number of days the stock value of retailer is zero	6 days	0 days

Fig. 10. Statistics for both control methods.

5. FURTHER RESEARCH

5.1 Metrics

The wishes of the chain operators as well as the viewpoints produced in theory are included when building the measuring system. Ideas on measuring the performance of the chain were presented by people involved in supply chain operative duties. These included measuring the profitability of every product for the whole supply chain and measuring the amount of time used in the different stages of the whole chain. In addition, financial metrics are used to reveal the amount of money tied up in the supply chain.

A simple analysis of costs associated with supply-chain operations is also produced. An example of such analysis is presented in figure 11. The picture reveals the phases of the chain responsible for most of the consumed time, and on the other hand of the most value added. The aim is to combine the cost aspects of the analysis with the actual simulation done in the project.

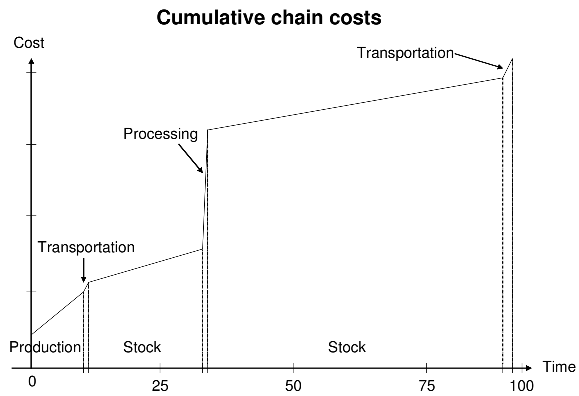


Fig. 11. Presentation of costs from the different chain operations in conceptual level

This provides a suitable tool for presenting not only the benefits in speed, reliability, and other metrics associated with different operation configurations of the supply-chain but also of the actual costs associated.

5.2 Forecasts as Control Input in Timber Products Industry

Factors affecting demand in timber products environment are seasonal effects, similar products of competitors (one cannot use product characteristics as competitive advantage) and price. Due to long life cycles of the products and mature markets time series models can be used for demand estimation.

In this project, the combination of three different models was used. These models were Multiple regression, Exponential smoothing and Arima models. Each of these models was tested separately but the separate results could not reach the level of the combination of these models. This kind of estimation is useful for production management because variance estimation is not needed (variance estimations cannot be grouped). In inventory management the variance estimation is essential and therefore Multiple regression is used for that purpose.

Demand forecasts are used in the whole supply chain i.e. for production management, inventory management, in sawmills and in transportation management. Therefore, forecasts are used as input information for the whole supply chain.

6. CONCLUSIONS

As simulation results show, the management of the whole supply chain can be significantly improved by using transparent control method instead of a traditional one. When combined with sophisticated demand estimations the control can still be improved: the basic logistics principle of right information to right place shows its strength here. With systems thinking it is possible to manage the complexity of a long supply chain and to understand that complex problems do not need complex solutions.

The value of the results gained is not on the new or sophisticated academic control or modelling methods but on the interdisciplinary research approach: the study brings together methods and tools of automation and control, modelling, logistics and demand forecasting. These all combined with real industrial cases make the study valuable: based on the results of the study the company involved has decided to take the following practical steps in supply chain management and control:

1. Increase the transparency in the whole supply chain by exchanging information for the whole chain, not for the nearest participant
2. Use demand forecasts as input information for the control and management of the whole chain
3. Involve its customers to produce the best possible demand forecast

For the company involved, it is important to concentrate first on internal development. After that, the opportunities to integrate with customers and partners in e.g. subcontracting and transportation will be studied.

REFERENCES

Angerhofer, B.J. and M.C. Angelides (2000). System Dynamics Modelling in Supply Chain Management: Research Review, *Proc. of the Winter Simulation Conference*.

Ballou, R.H. (1999*). Business logistics management: planning, organizing and controlling the supply chain.* 4th Ed. New Jersey. Prentice Hall. 681 p.

Business Process Trends. (2003). Second generation business process methodologies. **Vol. 1**, p. 12.

Carlsson, C. and R. Fullér (2000). A fuzzy approach to the bullwhip effect, *Proc. of Cybernetics and Systems '2000*, Vienna, pp. 228-233.

Chang, Y. and H. Makatsoris (2001). Supply Chain Modelling Using Simulation *International Journal of Simulation*, **Vol. 2.** , No.1.

Chen, Y-W. and G-H. Tzeng (2000). Fuzzy Multi-objective Approach to the Supply Chain Model, *International Journal of Fuzzy Systems*, **Vol. 2**, No. 3.

Christopher, M. (1992). *Logistics and Supply Chain Management. Strategies for Reducing Costs and Improving Services*. London, FT Prentice Hall.

Haussman, W. H. (2002). Supply Chain Performance Metrics. New earning strategies for supply chains. June 21. pp. 16.

Li, D. and C. O'Brien (1999). Integrated decision modeling of supply chain efficiency, *International journal of production economics*, 59, pp. 147-157.

MathWorks Inc. Online: http://www.mathworks.com/

Minner, S. (2001). Strategic safety stocks in reverse logistics supply chains, *International journal of production economics*, 71, pp. 417-428.

Petrovic, D., R. Roy and R. Petrovic (1999). Supply chain modelling using fuzzy sets, *International journal of production economics* 59, pp. 443-453.

Schönsleben, P. (1998). *Integrales Logistikmanage-ment: Planung und Steuerung von umfassenden Geschäftsprozessen.* Springer.

Towill, D. R. (1997). Forridge – Principles of Good Practice on Material Flow, *Production Planning & Control*, **Vol. 8.**, 7, pp. 622-632.