MODELLING OF THE MATERIAL FLOWS IN WOOD INDUSTRY COMPANIES

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ABSTRACT

The paper presents the systems of statically discrete and dynamic continuous simulation of the stock quantities, aiming at the optimization of an entire business process company. The design and behaviour simulations of a dynamic material flow model have been conducted in this study. Two simulations have been carried out: the statically Monte Carlo and the continuous system dynamic simulation. Authentic data of the stocks and suppliers were used in the simulation. The system dynamic simulation during the observed period of time and for particular case, yielded better results regards to lower stock quantities and lower invested turnover capital. Hence, models simulation of stock management may be successfully applied in wood industry firms. These models are intelligent system support in the process of computer-aided decision making.

KEY WORDS: woodworking industry, business management, intelligent agent, inventories, material flows, modelling, simulation

INTRODUCTION

Many models and methods to manage inventories have been developed. Most of them use different techniques that optimize material flows. However, there are no general solutions. Each task requires a specific technique to determine material quantity. In the research we use discrete statically and the continuous system dynamic simulation method. We believe it is a suitable answer for solving the inventory problem. Moreover, we are convinced that the methods are more than appropriate to forecast the future material requirements, too (Khouja 2003, Roy and Arunachalam 2004).

In this paper Monte Carlo has been used as a statical type of simulation where creating the samples from accidental variable values have been used in solving the problem. It means that material stock problem was stochastic. (Čerić 1993).

System dynamics is a framework for thinking about how the operating policies of a company and its customers and suppliers interact to shape the company's performance over

a period of time. System dynamics builds up an information feedback theory which provides symbols for mapping business systems in terms of diagrams and equations, and a programming language for making computer simulations. System dynamics is a scientific discipline with its own scientific methodology of investigating the behavior dynamics, modeling, simulation and optimization of primarily the most complex dynamic systems that have been scientifically studied and determined by real continued models, i.e. by a group of linear and/or nonlinear differential equations. It is also an actual application of the „System Thinking" to the processes of management of complex, dynamic, natural, technical and organization systems. This paper demonstrates the philosophy of the system dynamics continuous computer simulation of the behavior dynamics in the production and business management of the wood industry company. The system dynamic models are not based on any mass data processing but on the smallest quantity of data that yield most information on the studied laws of behavior dynamics in the organizational business systems (Pidd 2003).

Learning from modeling and simulation, illustrates developments in the model-supported case studies and workshops. It also describes the efforts now being made to understand the obstacles to group learning and to measure (objectively) the improvements in learning that derive from the use of models and gaming simulators. These methods are intelligent system support (Wooldridge, Muller and Tambe 1996).

It is important to collect data from history. In such a way the company will be prepared for the future. Traditional methods for solving the inventory problem have no forecasting abilities. To enable forecasting different methods could be used: time series, ARMA, ARIMA, etc. The problem is how to incorporate them in a simple and exact model of a real system. Furthermore, the model has to be suitable, neither too simple nor too complex. It is the modeling theory, practice and way to use the obtained results in the future. The future is always uncertain-only the disturbances are certain. That is why we are convinced that the new intelligent modeling-learning approach could be the right way to solve the inventory problem. Moreover, the experimental results that are in the paper support the reason why we should use system dynamics. Simple but adaptable models have to be made to enable the qualified models that could help the decision makers.

The data we have used have been collected from a real system. Such approach enables the comparison of forecasting given by the model with the results obtained in the real system. The aims of the research were:

- to analyze the current state of inventories in the real wood industry company,
- to establish the influence factors in material flows,
- to define the optimization criterion,
- to develop the models capable of simulating the material flows in a real wood industry company,
- to select the most appropriate simulation model, and
- to show that by minimizing the inventory stocks and the invested turnover capital it is possible to improve the business-and manufacturing management processes in wood industry.

The decision is impossible without alternatives. Traditional methods are suitable to determine the outputs in inventory management. In contrast to the forecasting methods, the modeling-learning offers a great advantage-it could join different methods and combine them in a powerful decision support. No other method is capable of doing it in such an amazing way. Therefore, the system dynamics provide a frame of how to solve a problem intelligently; it is an intelligent tool that enables modeling and learning games. Another advantage is that it enables

parallel simulation of both business and manufacturing processes. By building such a complex model, the decision maker can validate the inventory model in the context of business and manufacturing system and the related environment. Experimenting with different scripts that could simulate the future enables the future to be more predictable. To summarize, whatever simulates the future, the management will know the best solution. It is because they know the short and middle-term consequences of their decisions. Therefore, they will be able to make good decisions and to keep the company in a near-optimal condition according to the material resource plan to maximize the invested turnover capital. It would, thus, be convenient to for the whole business of a company (Benić and Grladinović 1997, Demoč and Grladinović 1997).

THE MODEL

The research promotes a modeling-learning simulation model that optimizes inventories in the wood industry company. Therefore, it is a novelty in solving the inventory problem-we did not find any research that uses such an approach in solving the inventory problem.

The model we developed uses data that have been calculated by a deterministic mathematical model. To get a sufficient amount of data to study the material-flow principle, the minimal amount of data processing has been used. In many cases the mass data processing could be approximate. It is because the improved behavior in a wood industry company depends on its structure, business policy, vitality and economic conditions in behavior. The structure of a manufacturing system is complex whether the company is 'small' or 'big'. Therefore, it is reasonable to look at the system through different, small but self-sufficient, sub-systems. It is close to the tendency of using artificial intelligence (AI) in principle and practice of building computer-based models. The essence in such an approach is to build a model of the system that consists of intelligent agents. The agent is the unit that solves a specific task or group of tasks during the process of decision making according to the goal of a system. It has a limited amount of memory and knowledge of environment, a limited knowledge of constraints and intentions of other agents and a limited amount of resources. The agent produces a solution (Benić and Grladinović 1997, Proudlove, Vaderá and Kobbacy 1998).

The material supply system is important for each wood industry company. The aim of the system is to estimate the accumulations in the physical values of the goods. The material-flows connect the facilities that build a manufacturing process. The management policy applies material and information flows to determine the business policy and to keep the company in a good condition. The state of the materials used the manufacturing process implies the supply periods that require a material and production cycle such as rate of materials used to accomplish the manufacturing process. When the model of material supply system is an instance in some more complex human-computer decision making system (Hafees and Abdelmeguid 2003).

The behaviour of the enterprise is a result of its structure and business policies. Its improvement as a dynamic business system depends on its structure, business policies, behaviour dynamics and business conditions (egsogenic influences).

Structure of the production system, i.e. its purchase-production system, consists of accumulation physical value elements, material flows among those system structure elements, and management policies for those material information flows, which we use to establish enterprise business policies. (Sujová 2004).

The real system model consists of input stock elements, part stock quantities and output stock elements. (Fig. 1)
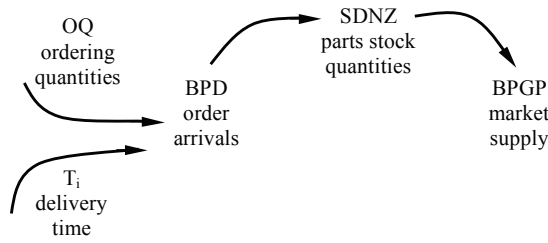
Fig. 1: Real stock system model

Legend: OQ – ordering quantities (pcs), T_i – delivery time (days), BPD – order arrivals (pcs/day), SDNZ – parts stock quantities (pcs), BPGP – market supply (pcs/day)
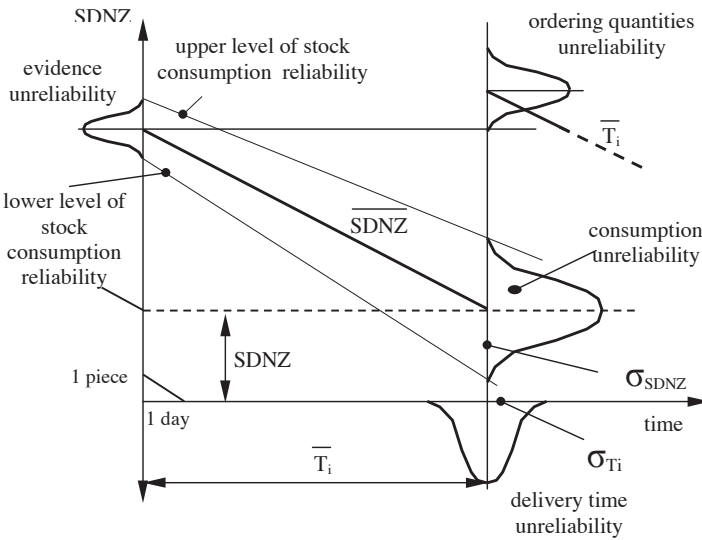
Fig. 2: Real stock system model analyses – presumption for simulation model designing

Legend: SDNZ – parts consumption in T_i (pcs), T_i – delivery time (days), $\overline{T}_i$ – average delivery time (days), $\overline{SDNZ}$ - average part consumption in T_i (pcs), σ_{SDNZ} – standard deviation of part consumption in T_i (pcs), σ_{Ti} – standard deviation of delivery time (days)

Discrete static simulation model consists of parts in the input stock, part stock quantities and parts in the output stock. (Fig. 3)

Fig. 3: Discrete static simulation model

Legend: OQ – ordering quantities (pcs), T_i – delivery time (days), $\overline{T}_i$ – average delivery time (days), BP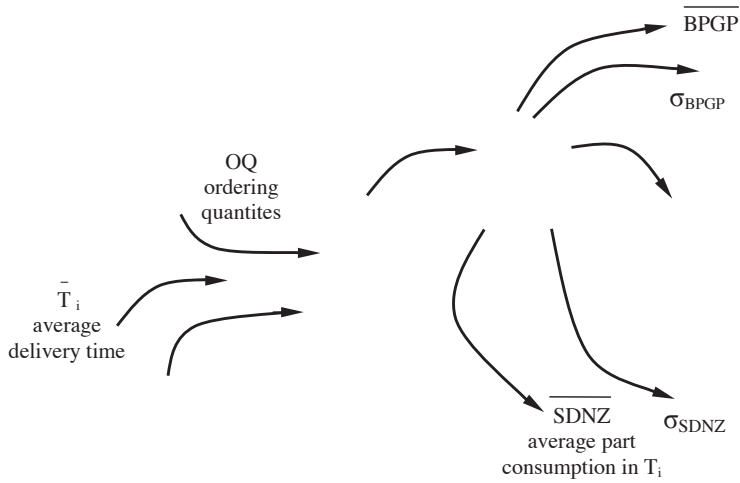D – order arrivals (pcs/day), BPGP – market supply (pcs/day), $\overline{BPGP}$ – average market supply (pcs/day), σ_{BPGP} – standard deviation of market supply (pcs), σ_{SDNZ} – standard deviation of parts consumption (pcs), SDNZ – parts consumption in T_i (pcs), $\overline{SDNZ}$ – average parts consumption in T_i (pcs)

Monte Carlo simulation is performed by the following mathematical model:

$$SDNZ = \overline{SDNZ} + u \times \sigma_{SDNZ} \tag{1}$$

$$\overline{SDNZ} = T_i \times \bar{q} \tag{2}$$

$$\sigma_{SDNZ} = \sigma_q \times \sqrt{T_i} \tag{3}$$

where SDNZ – parts consumption in T_i (pcs), $\overline{SDNZ}$ – average parts consumption in T_i (pcs), T_i – delivery time (days), $\bar{q}$ - average value of parts consumption (pcs), u - 5 % risk - P(1,64), σ_{SDNZ} – standard deviation of parts consumption in T_i (pcs), σ_q – standard deviation of parts consumption (pcs)

The model in Fig. 4 could be an example of an intelligent agent. Fig. 4 describes the system that delivers material in short terms using the positive (+) cause-and-consequence link. The shorter the production cycle is, the smaller the material stock is (Munitić 1990).

Fig. 4: Causal loop diagram

Legend: BPD – order arrivals (pcs/day), SDNZ – parts consumption in T_i (pcs), BPGP – market supply (pcs/day), KRND – parts delay (pcs/day), SND – rate of parts purchase (%), VINP – parts delivery time (days), FPND – orders increasement factor, ZND – wanted parts level (pcs), PBFP – average level of products finalization (pcs/day), OVZD – expected duration of stock (days), KSP – constant production level (pcs/day), ST – change of production level, VUBPG – production information time level (days)

Therefore, the negative (-) cause-and-consequence link must be established, too. The model that simulates a management policy uses different values of delivery time between a manufacturer and suppliers. The different scripts are of essence when simulating an acceptable management policy to design an inventory behavior and to study its influence on the business and manufacturing processes (Munitić 1990). To calculate the variable of level the following expression has been used:

$$\text{L} \qquad \text{L.K} = \text{L.J} + \text{DT} \times (\text{RA.JK} - \text{RS.JK}) \qquad (4)$$

where L.K is a new system-level at K-th moment, L.J is an old system-level at J-th moment, DT is an interval between two consecutive calculations (J-th, K-th and time-axe t), RA.JK is a change in material flows through JK-th period and RS.JK is a change in material flow level at JK-th period.

The expression in (4) presents the main interaction. It is the only instance in the computer-based support system that has to be adopted depending on the specific case. Other instances are common for all cases.

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The model given in the Fig. 5 is capable of adopting input and output material flows using non-linear interdependence. The simulation with the modeling-learning approach is interactive and takes care of all the relations between the model and the system, their resources and the environment. The simulation follows part time period and DT element sum changes in the individual material-flows. Therefore, the properties of the entire, interactive and self-repeating process are obtained and suitable business results could be established (Munitić 1990).
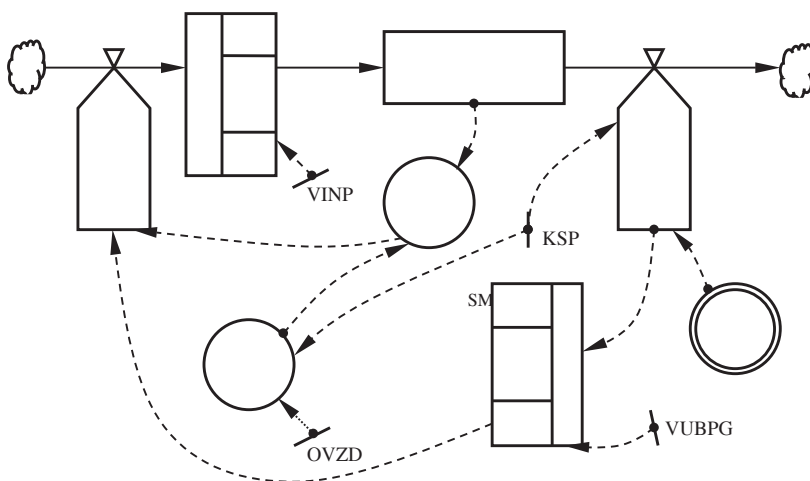

Fig. 5: Flow diagram

Legend: BPD – order arrivals (pcs/day), SDNZ – parts consumption in T_i (pcs), BPGP – market supply (pcs/day), KRND – parts delay (pcs/day), SND – rate of parts purchase (pcs/day), VINP – parts delivery time (days), FPND – orders increasement factor, ZND – wanted parts level (pcs), PBFP – average level of products finalization (pcs/day), OVZD – expected duration of stock (days), KSP – constant production level (pcs/day), ST – change of production level, VUBPG – production information time level (days), DEL3 – exponential function of delay – 3rd order of material flow, SMOOTH - function of exponential averaging of information flow

In the research DYNAMO simulation language has been used. The computer-based simulation model was made in BASIC programming language and SYSDYNS system dynamic SW package. The reason for using DYNAMO is its high symbolic value suitable for building models of continuous complex dynamic systems. The basic elements in DYNAMO respect system dynamics and enable efficient computer simulation.

Mathematical model in DYNAMO compiler is described in Kompjuterska simulacija uz pomoć sistemske dinamike (Munitić 1990).

THE SIMULATION

Following section reports on simulation results. The model that has been built for the simulation experiments uses data collected from a real system such are:
– the material delivery time,
– the inventory level,
– weekly demands, and
– market demands.

The management policies were selected according to material resource plan. It is because the primary goal in the research was to study product inventories and market demands.

Let us now give some general observations. They have been established through simulation experiments.

1. The inventory level depends on demands, material delivery time and the manufacturing cycle in which final products has to be delivered. If the material delivery time is shorter, the stocks will increase up faster. If the manufacturing lead time decreases, the stocks will decrease faster and the product demands will be met in a shorter time. In this case the supply time is of significant influence.

2. If delays in supply are build in the simulation model considerable disturbances will be met. Stocks accumulate at slower rates, production cycles are longer and the final product inventories are lower. The entire production cycle is longer.

SIMULATION RESULTS

Real material stock data during the year were used in simulation models.

Tab. 1: Monthly stock during one year in a real system of a small woodprocessing company

	Month											
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
	pcs											
Monthly part stock level during the year	1 385	2 196	908	498	1 625	2 011	315	282	1 349	2800	311	1128
Average monthly part consumption during the year	1 234	1 234	1234	1 234	1 234	1 234	1 234	1 234	1 234	1234	1234	1234

ΣQ = 14 800 pcs – total parts consumption during the year
$\bar{q}$ = 1 234 pcs – average monthly parts consumption during the year

Following results shown in table 2 were established by using discrete static Monte Carlo simulation:

Tab. 2: *The results of the discrete static Monte Carlo simulation*

Simulation (years)	Month											
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
	pcs											
Total parts consumption during the year	10 859	10 519	10 817	10 754	10 807	10 737	10 703	10 781	10 608	10 734	10 674	10 730
Average monthly parts consumption during the year	1 085	1 051	1 081	1 075	1 080	1 073	1 070	1 078	1 060	1 073	1 067	1 073

$\bar{q}$ = 1 072 pcs – average monthly parts consumption during the year

Based on the established system of dynamic modelling and its mathematical model following results were achieved:

Tab. 3: *The results of the system dynamic simulation = 948 pcs – average monthly parts consumption during the year*

Simulation (year)	Month											
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
	pcs											
Total parts consumption during the year	9 559	9 336	9 532	9 553	9 526	9 482	9 457	9 507	9 392	9 477	9 441	9 476
Average monthly parts consumption during the year	955	933	953	955	952	948	945	950	932	947	944	947

$\bar{q}$ = 948 pcs – average monthly parts consumption during the year

It could be noticed that dynamic simulation gave the lowest level of parts stock during the year for observed real case.
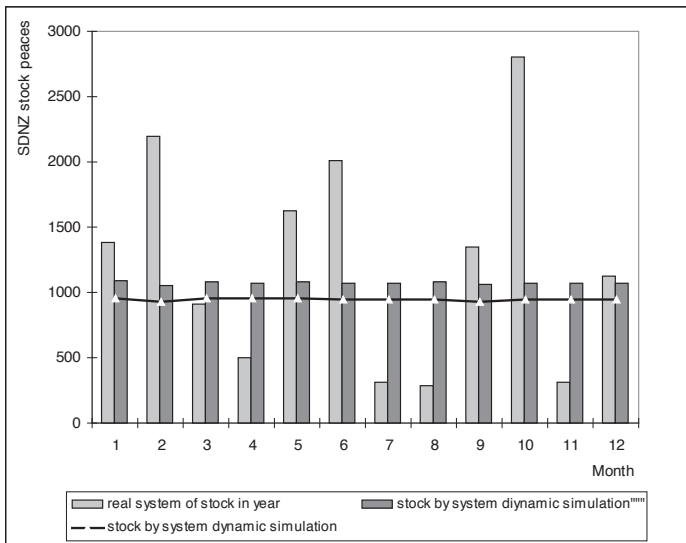
Fig. 6: Parallel overview of the parts stock level during the year in the real system, descrete static and system dynamic simulation models

THE INFLUENCE OF MANAGEMENT POLICIES

The business policy is a key to success. The simulation has been given some interesting conclusions valuable for the business policy, too.

The necessity to coordinate the inventory management and the purchasing has been identified due to simulation results in different management policies. The time-delays in the information/material-flows have to be eliminated, too. Furthermore, it is good to reduce the delivery time and to forecast the future demands.

The improvement in the information/material-flows between a supplier, a manufacturer and a customer favorably meets requirements.

CONCLUSION

The inventory problem is significant in wood industry companies. Inventories affect at the manufacturing and business results. Therefore, the improvement in the material-flows managements is a way how to extent business results. The research presented in the paper promotes intelligent modeling-learning approach. The approach uses statically Monte Carlo simulation and continuous system dynamics method. The use of system dynamics simulation approach has indicated that the improvement in the material-flow management is possible and profitable. The conclusions are:

1. The product demand is the most significant factor in the inventory management system model.
2. If the changes in demands are unexpected, the fluctuation in material-flow reduces high inventories.

3. The factor of enhanced material orders was integrated in the model. The simulation has shown that it is a good rule for material-flow management in cases where product demands are unexpected.
4. If the demand is continuous the material-flow meets product demands in a very short time.
5. The research has promoted intelligent techniques in demands monitoring, material management and supplier control in the material-flow management. Those techniques are improvement to existing. They could bring benefits not only in the inventory management but also in invested turnover capital. In such a way the entire business of wood-processing company could be more valuable.
6. The selection of supplier must be careful. The supplier has to be reliable according to quantity, quality and terms (just-in-time manufacturing philosophy). That is how to cut down the inventories and to reduce turnover capital.

To be intelligent in business and management means reasoning about management in business and manufacturing. The tasks, such is the inventory problem, have to be solved intelligent. How to do it is to use the principles of intelligence and appropriate intelligent techniques. The modelling-learning combined with the system dynamics and simulation is intelligent way to do it. The tool how to realize it is to developed an intelligent agent. The agent has task to enable 'what if' analyses and simulation to help a decision maker to improove business results. The research developed the intelligent agent that enables suppliers and material orders monitoring. The goal of intelligent computer-based program, that has been developed, is to find a strategy how to minimize stocks and maximize the turnover capital that has been invested in inventories. The intelligence is in primary the property of humans. The computer system that pretends to be an intelligent one has to support and to improve human capabilities. It would improve significantly the entire business in wood industry company.

The perspective of the further research is to developed similar intelligent solutions for other business and manufacturing management problems and tasks. In such a way it will be possible, step by step, to improve the business and manufacturing processes to make them more rational than before. The intelligent way how to do it is to coordinate the use of human and computer resources and to improve the efficiency of both. It requires so little and offers so much. Solutions can be applied also in technological processes in like manner.

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