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USING DISCRETE EVENT SIMULATION IN SUPPLY CHAIN PLANNING

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ABSTRACT

Supply chains are difficult to plan because they involve complex relationships and dynamically changing variables that influence supply chain performance. In this paper, discrete-event simulation (DES) is evaluated in order to identify its appropriateness as a technique in supply chain planning. A DES model was developed as part of a case study, and is used in this paper to determine whether DES is an appropriate technique for unraveling the complexity of supply chains. The DES model represents a retail supply chain focusing on order and material handling process behaviors, and is based on data from an on-site study of the retail supply chain. One result of developing and using the DES model is that insight into the system parameters and their interaction with their context is obtained. DES could be used for analyzing and evaluating dynamic aspects as well as the influence of variance on supply chains, which can be used to support decision making.

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Furthermore, DES has the ability to tell how a supply chain performs and behaves over time when different rules and policies are applied. Testing different scenarios by adjusting parameters and procedures means that supply chain performance and behavior can be explored without disrupting the real system. This in turn means that DES may be confidently used as a technique in supply chain planning.

1. INTRODUCTION

In order to achieve a competitive advantage, supply chains are continually faced with challenges to improve their processes and to adapt to customer demand. Effective supply chains are those designed to deliver products and services promptly and reliably, at low cost and with high quality. To accomplish this, supply chain processes must be effectively coordinated. The problems associated with supply chains are often not simple and easy to understand. Fluctuations in demand and production change dynamically, which makes supply chains complicated to grasp (Seppälä & Holmström 1995). Supply chain decisions and planning are therefore a complex matter. One technological approach to tackling this is to develop supply chain models for analyzing operational, tactical and strategic decisions affecting the supply chain, thus helping to improve supply chain performance (Shapiro 2001).

Some models used to study supply chains focus on specific aspects and limited parts of the supply chain, e.g. route planning models (Seppälä & Holmström 1995), while others consider a wide range of aspects and consequently become very complex. The important thing is to use a model that provides a holistic view of the supply chain that prevents sub-

optimization (Chan et al. 2001). At the same time, the model should have the ability to illustrate all the important aspects of the supply chain that enable the user to draw conclusions about the real system.

The objective of this paper will be to determine whether DES could be an appropriate technique in supply chain planning. A DES model was developed as one part of a case study, and is used in this paper as an example of supply chain analyses and planning. A brief introduction to the case study will be presented. The DES model represents a retail supply chain focusing on order and material handling process behaviors.

2. FRAME OF REFERENCE

2.1. Terms and Definitions

The words *model*, *modeling*, *simulation*, *deterministic* and *DES* can be used by different people in different situations to describe different things. Therefore, before discussing the use of DES for modeling supply chains, some terms have to be defined and discussed.

In this paper a model is defined as "*a representation of a system for the purpose of studying the system*" (Banks et al. 2001). A model is a simplification of a system, but contains those components that are identified as relevant to the problem under investigation. Models are used to gain insight or predict future performance of a system. Modeling refers to the process of creating a representation of a system.

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Simulation, according to Banks et al. (2001), is an "*imitation of the operation of a real-world process or a system over time*". A simulation model is a descriptive model that is developed to better understand relationships and operations over time as a function of policies and parameters. Simulation models are mathematical, and can be classified as being static or dynamic, deterministic or stochastic and continuous or discrete. Dynamic simulation models represent systems that change over time, while static simulation models represent systems at specific points in time. Deterministic models do not contain random variables, and have known inputs that result in a unique output. A stochastic simulation model has random variables, which lead to random outputs. In discrete systems, variables only change at discrete sets of points in time, whereas continuous models change their variables continuously over time. In this paper a DES model is considered to be stochastic, dynamic and prepared on a computer.

2.2. Simulation in supply chain planning

Supply chain planning takes place on three hierarchical levels dependent on the time horizon for the planning: operational, tactical and strategic (Ballou 1999). Operational planning involves problems such as timing and sequencing of decisions. Tactical planning is concerned with resource adjustment and allocation, while the goal of strategic planning is to identify and evaluate resource acquisition options to improve the efficiency of the supply chain (Shapiro 2001). Depending on planning level, different goals are set and therefore different modeling techniques and approaches are used (Hicks 1999). A simulation cannot produce the optimal supply chain structure or suggest what supply chain design to select. A simulation can,

however, tell how the design performs and behaves over time when different rules and policies are applied (Shapiro 2001).

Simulation could be an effective technique to help analyze supply chain issues, because it can be applied to problems that are too difficult to model and solve analytically. Many analytical models only take a few variables into consideration. This simplification could result in a model that is not a realistic representation of the system. Simulating a supply chain is complex because a model must include several processes. However, to ignore some processes could lead the simulation model to ignore critical functions and activities that affect the performance being measured. To define the processes involved and develop a model that provides the user with a holistic view of the supply chain, thus preventing sub-optimization, is thus a fundamental step in simulating supply chains.

A major drawback of static models is that they do not incorporate the dynamic aspects of the supply chain that are important for its performance. Simulation is a well-known technique for investigating time-dependent behaviors in complex and uncertain systems (Banks 1998). Important examples of dynamic aspects in supply chains are varying lead times and changing market demand over time. Variance is another reason why simulation is an appropriate technology in evaluating and analyzing supply chains. Using simulation will allow the user to understand the implication of variances on the supply chain, like labor variance, material variance, and most importantly, demand variance. Using deterministic values in simulation models can result in response values far from the real system responses (Bekker & Ssyman 1999).

Making it possible to explore policies and operating procedures is one of the greatest advantages of simulation (Banks 1998). Different experiments can be conducted without disrupting the real system or claiming operational resources. Further, users can examine the effect and influence on processes and activities in the supply chain. This ability to evaluate "what if" scenarios with a variety of inputs could make simulation a useful technique for analyzing supply chains.

3. CASE STUDY

This section presents a case study in which DES was used to analyze a retail supply chain. Based on the DES model developed in the case study, we will consider whether DES could be an appropriate technique in supply chain planning.

3.1. Case study objectives

The general objective of the case study was to investigate how the supply chain process would respond if a wireless identification technology were applied to unit loads throughout a retail supply chain, without disrupting the real system. Analyzing the effect of changes in processes could improve understanding of the technology. Furthermore the objective was to present the effects of wireless identification in a retail supply chain clearly.

3.2. Methodology

According to Yin (1994), case study is empirical inquiry that investigates a contemporary phenomenon within a real-life context. Case study is an appropriate research method when answering questions like "how" and "why". Moreover, the method is an in-depth analysis that copes with

questions in which there are more variables to be considered than specific data points (Yin 1994). This supports the use of the case study method here, since the variables analyzed have complex contexts and require in-depth analysis to explain their interaction. The study was also concerned with understanding "how" and "why" the retail supply chain functions.

The selection of cases is an important step when conducting case studies (Eisenhardt 1998). A retail supply chain in the Netherlands was chosen as a single case study because access and information were available. The retail supply chain consists of several actors: producers, manufacturers, distribution centers (DC), retail outlets and consumers; see Figure 1.
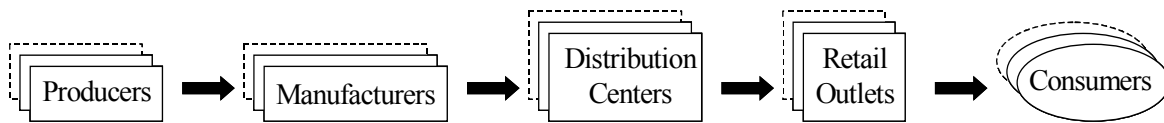

Figure 1. Schematic diagram of the retail supply chain.

The case study approach can use several techniques to collect data (Yin 1994). In this case study archives, observation and interviews were the techniques used, and the data were collected from an on-site study of the retail supply chain.

3.2.1. Discrete-event simulation

DES was used for analyzing how the process would respond when wireless identification technology was applied in the retail supply chain. A DES model consisting of a producer, DC, a retail outlet and consumers was developed. The model of the retail supply chain represents those processes behaviors that were considered important. The order process was identified

as the main focus of the study, so this process has a central role in the DES model. The ordering process is tightly coupled with the individual material handling processes such as the order picking in the DC. Therefore the material handling process was also included in the DES model and considered as a vital process. The performance variables measured to analyze different scenario results were e.g. variables that control:

- Material handling efficiency
- Consumer service
- Inventory levels
- Lead times

The number of actors involved in the case study reflects directly on the complexity of the assignment to model the retail supply chain, and therefore the size of the problem. DES was identified as a technique for solving this complex problem, since solving it analytically was not viable. DES handled both stochastic and dynamic behaviors, which is the basic problem when the objective is to analyze how a supply chain design behaves and performs over time when different rules and policies are used.

Developing the DES model required extensive gathering of input data, model building, validation and verification. These simulation steps were time consuming and required simulation expertise, especially when modeling complex systems like supply chains.

The computer software (tool) used to develop the retail supply chain model is mostly used for the simulation of material handling systems. The software uses 3D animation and is powerful in its descriptions of material handling

systems (Banks 1998), but it is also considered to be a flexible software that can be applied in other areas.

4. RESULTS AND DISCUSSION

The result from the case study is that DES can be an effective technique in supply chain planning. In the case study, DES had the ability to tell how the retail supply chain performed and behaved over time when the wireless identification technology was applied. DES enabled users to observe and analyze the dynamic behavior of the model, which can be used to support decision making. With DES, a realistic representation of the retail supply chain processes and activities was achieved, and this provided a holistic view of the supply chain so that sub-optimization could be avoided. If the DES model had represented only one actor, the benefits from using wireless identification throughout the retail supply chains would have been ignored.

The case study has shown that DES is an appropriate technique when modeling both operational (material handling) and tactical (order process, inventory management) supply chain scenarios. The DES model developed had the ability to illustrate how the material handling processes performed and behaved when different operational procedures were applied. For example, wireless identification technology has the ability to automatically identify goods, which facilitates automatic control and obviates manually re-labeling of goods, for example. The response from the model was that the material handling procedures became faster and more accurate, resulting in less utilization of resources. In tactical planning, DES had the ability to tell how the retail supply chain performed and behaved when different ordering rules were used. For instance, when changing the information flow to a real-

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time information system the point of sale data was shared with all participants of the retail supply chain, which the model responded with, for example lower lead times and decreased utilization of resources.

Conducting different "what if" scenarios was appropriate in the case study since the retail supply chain was not ready to go "live" with the wireless identification technology. The actors in the supply chain did not have a clear picture of the advantages or the disadvantages of the technology, which made studying different "what if" scenarios with DES suitable for exploring the effects of the wireless identification technology. Experimenting with the model provided an insight into the behaviors and performance of the retail supply chain. Furthermore, insights into the variables' interactions were found, and their effects throughout the supply chain were observed. This insight into the supply chain behaviors and parameters that control performance became clearer, thereby improving the overall understanding of the retail supply chain. The model developed is an example of how such an insight could be gained because it investigates how processes could respond when applying wireless identification throughout a supply chain.

Thanks to animation, users could quickly and easily develop an overall understanding of the model that accurately represents their system. The visualization of the wireless identification technology in the retail supply chain yielded greater understanding of the concept of wireless identification technology. In addition, the evaluation and analyses of the supply chain with DES were supported by visualization of material flow and activities. Without being an expert, one could gain an understanding of the retail

supply chain through watching the animation. The visualization was also used to support the verification and validation of the model.

As a DES model increases in size and realism, more resources have to go into the development of the model. Simulating every process and activity in the supply chain in detail would be a manager's dream. But the development of a supply chain model often involves compromises between detail level and number of built-in processes. Not all of the activities and processes of the retail supply chain were embedded in the model, since a high detail level was given priority to accomplish a realistic representation of supply chain processes. With the same resources, choosing to model all activities and processes would lower the detail level, resulting in a rough model with a lower abstraction level. However, a rough DES model could easily be adapted and reused in different applications and in different contexts. In a situation where data is limited and industrial decisions take place rapidly, it could be more advantageous to build a rough DES model.

5. CONCLUSIONS

The result from this paper is that DES can be an effective technique in supply chain planning by enabling evaluation of dynamic aspects as well as the influence of variance on supply chains, which can be used to support decision making. DES has the ability to tell how a supply chain design performs and behaves over time when different rules and policies are applied. With DES, a realistic representation of supply chain processes and activities can be achieved, which should provide a holistic view of the supply chain that prevents sub-optimization. In this paper, DES has been

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shown to be an effective technique for modeling and analyzing supply chain decisions in the order and material handling processes.

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