Discrete Event Simulation in a Virtual Enterprise Environment: a Case Study Reflection of Multiple Developers

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KEYWORDS
Discrete Event Simulation, Virtual Enterprise, Multiple Developers.

ABSTRACT

Today, making decisions in a distributed production system, like a Virtual Enterprise [VE], have few support tools. This paper discusses how Discrete Event Simulation [DES] can be used in a VE environment. A DES model was built involving multiple developers who were individually responsible for one part of the model. In this case study, incremental development methodology has been used together with a methodology for conducting DES projects. The paper presents reflections from the developers and gives recommendations for applying DES on a VE. The most important reflections were to formulate a well defined goal for the project as a whole, to start with integration as early as possible, and to have tangible goals.

INTRODUCTION

In recent years there has been a growing attention concerning competitiveness for small and medium-sized enterprises [SME]. More efforts are being exerted on planning and managing flexible and efficient organisation and collaboration network between companies (Porter 1998). Collaborating in production networks has, by researchers, been given many names. Names such as Dynamic Network (Miles and Snow 1986), Intelligent Enterprise (Quinn 1992), Virtual Organisation (Venkantraman and Henderson 1998), and Agile Virtual Enterprise (Goranson 1999) are some examples describing similar concepts.
The Virtual Enterprise[VE] is based on a temporary cooperation with the capability of fulfilling a specific customer order. The order, often classified as a short business opportunity, is divided between the collaborating companies, each adding their specific competence to the divided value chain. A structure with different actors connected to the collaborating companies has been developed for an efficient handling of activities within the VE. Analysis of the VEs lifecycle has also been investigated, resulting in a Virtual Enterprise Reference Architecture and Methodology [VERAM]. Reid et al (1996) and GLOBALMAN21 (2002) describes the phases a VE goes through in its lifecycle. However, there is still a lack in the VE research concerning supporting tools for the decision making. In this paper the use of DES in a VE environment will be discussed. A case study in this environment, done by 25 MSc students at Chalmers University of Technology, will be presented and reflections from this will be discussed.

THE VIRTUAL ENTERPRISE CONCEPT

The research area of Virtual Enterprise is a growing and multidisciplinary one, which requires precise definition of the concept. Afsarmanesh et al (1997) describe VE in the following way:

"VE is a network of enterprises that constitute a temporary alliance, in order to share their costs, skills, and resources, in supporting the necessary activities towards the exploitation of fast-changing opportunities for product or service requests and competitiveness in a global market."

Companies, which share common interests, form a network which works as a platform towards customers. When the network receives an opportunity, the firms that are suited to manufacture the order are joined together in a VE where the whole production system is distributed between the firms, Figure 1. The network have to be efficient in forming different VE constellations to handle different orders.

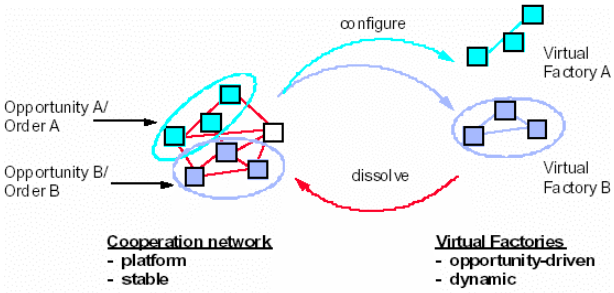

Figure 1: Establishment and management of cooperation (Virtuelle Fabrik 2002)

Advantages in collaborating in a Virtual Enterprise are, for example increased response speed to the customer, flexibility, reduced costs, and the fact that each company can focus on its core competence (Afsarmanesh et al 1997; Goranson 1999). Flexibility

Proceedings 15th European Simulation Symposium
Alexander Verbraeck, Vlatka Hlupic (Eds.)
(c) SCS European Council / SCS Europe BVBA, 2003
ISBN 3-936150-28-1 (book) / 3-936150-29-X (CD)

can be achieved by using overcapacity within the collaborating companies. Therefore no, or very small, investments have to be made. A manufacturer that has all operations in-house has better control over the complete production system. But is not as good as a VE to manage the flexibility in volume and mix that comes with handling many different orders.

DECISION MAKING IN VIRTUAL ENTERPRISES

A VE is characterised by its flexibility of synchronising companies in different combinations due to different orders, figure 1. In this environment there is a need for a supporting tool that helps decision maker in the offering, planning and execution phase. These decisions will secure the delivery time, give an opportunity to plan production and affect the priority within companies.

During a VEs lifecycle there are a number of decisions that have to be made. In early phases possible constellations for managing the production is investigated. This is done by dividing the product into operations and tasks that can be summed up in a value chain. The VE constellation is based on the collaborated companies capacities and capability of conducting the operations. The next phase is to schedule these operations so that lead times can be secured both within the VE and toward customer. In this phase obligations from the VE should be synchronised with each of the companies obligation in it self. Since companies have different obligations towards other customers and maybe also to other VEs, a priority list have to be followed. In a VE the relations have to be trustful to achieve a long-time benefit.

VE works in an environment where the configuration between companies can change fast, depending on the customer order size. This complexity makes it hard to optimise the distributed production system, however to be competitive there is still a need to increase the efficiency of the production system as a whole.

DES IN VIRTUAL ENTERPRISE

Building a DES model of a VE, involves both the attended companies and the value chain that the product is divided into, figure 2. The approach used in this section is from a start-up view of using DES to develop a complete new VE.

While building a VE simulation model there is a need for each company to have a model representing their production which can be added to the VE model. Since Virtual Enterprise is a conflicting and changing environment, updating models plays a vital role.

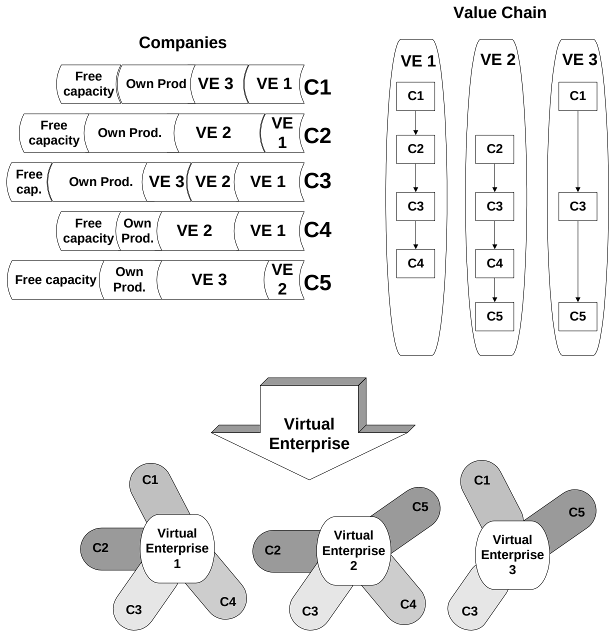

Figure 2: Configuration of collaborating companies in different VEs

Being successful with this kind of complex project is a difficult task due to the many different developers that are involved during the project, and the fact that the process of building a simulation model is classified as an art, according to Pegden et al (1995):
"Model building requires special training. It is an art that is learned over time and through experience. Furthermore, if two models of the same system are constructed by two competent individuals, they may have similarities, but it is highly unlikely that they will be the same."

On the other hand, if two or more developers would build sub-models representing one large system together, how would this model consisting of many connected systems act? To answer this question a case study was prepared that would involve multiple developers, where each developer was building a production unit of the complete model.

Multiple Developers

Building a simulation model is a time consuming task and by adding multiple developers working with the model it is expected that the development lead-time would be reduced. But with more developers involved the communication complexity is increasing as figure 2 shows. The developers need to build their models with the same level of abstraction, enabling the aim of the model to be met. A name convention is also needed, which secure transparency in communication between sub-models. Since the aim is to develop a model representing the VE, open communication can reduce sub-optimisation which reduces the lead time in the model building phase. The complexity of figure 3 calls for a methodology to support model building with multiple developers. Primarily to make sure that conflicts, where for example entities using the same information, is avoided, or secured.

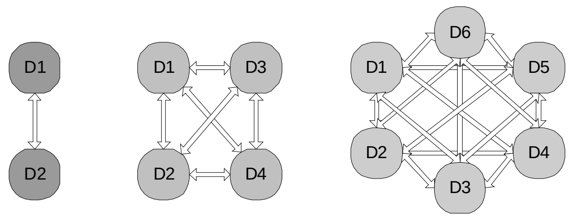

Figure 3: The increasing number of communication channels with multiple developers (Babich 1986)

There is a need to work in a structured manner to be able to verify the complexity represented by the VE. Incremental development is one way of structuring the development of a complete model.

Incremental Development

One common recommendation when building a simulation model is to Keep-It-Small-and-Simple, KISS, which the approach of incremental development also support (Randell et al 1999). Figure 4 shows how incremental development can be used in a VE environment. In three stages that have the same goal, represented by the background arrow, but differ in the level of abstraction; VE, Factory and Machine level. In the first stage, VE level, the model is built up by "black boxes" representing different areas within the company. Building this model is swift due to the low level of detail, which also makes it poor in supporting the decision making in an overview analysis of the system.

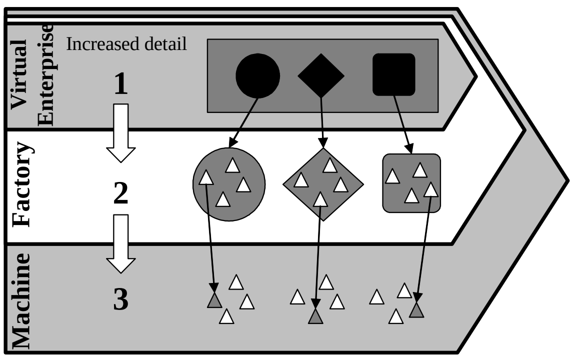

Figure 4: Incremental development of a simulation model

In the next stage, Factory level, the boxes open up and more details are added to them. With this model the level of detail is increased and with this also the possibilities for analysis. In the last stage, Machine level, the abstraction is down on the lowest level where details for each small entity are added.
Modularisation as shown in Figure 4 reduces the complexity of the model building phase of a simulation study. Although complexity between different entities within the model itself is reduced by modularisation, the complexity grows by the number of entities in the model.

In a Virtual Enterprise all developers in Figure 3 represent a company on the highest level of abstraction. The goal for working efficiently with DES in a Virtual Enterprise environment would be to have every company's model worked as a "plug-and-play" model that could be added to the VEs distributed production system. To do this the level of abstraction has to be decomposed and well defined both within and between each node in the VE.

Success factors

Since DES is a tool that have been used for many years, factors for succeeding in this projects are well documented. Still we find cases studies that fail in the most fundamental areas (Johnsson and Johansson, 2003). Following are some of the most well known success factors from literature (Banks et al 2001; Shannon 1998; Williams 1996).

- Have clearly defined goals.
- Have adequate resource available to successfully complete the project on time.
- Have management's support and have it known to those who supplies us with information and data.
- Assure that the necessary skills required available for the duration of the project.
- Be sure that there are adequate communication channels to the sponsor and end users.
- Have a clear understanding with the sponsor and end users as to the scope and goal of the project as well as schedules.
- Have good documentation of all planning and modelling efforts.

CASE STUDY: USING MULTIPLE DEVELOPER IN DES

Introduction

The case study, carried out by students as a part of a project course at Chalmers University of Technology, was conducted on a company with traditional manufacturing, including both machining and assembly. The company's main interest in this analysis was to find opportunities to reduce the lead time and improve the accuracy in the delivery process. Recently the company changed their manufacturing layout from focusing on manufacturing process to a more flow orientation one and made lead time a prioritised area. One big problem for the company is the customised product variance which is effecting the production planning. To cope with the huge variance the company produces batches of all the different components and stores them in modular assembly units to reduce the lead time from order to delivery.

Method

The students were divided into eight groups. Seven of these groups were responsible for one production unit each and the last group was responsible for the complete factory model. Figure 5 shows how operations in the production flow were divided into seven areas, each representing a company in the VE environment.

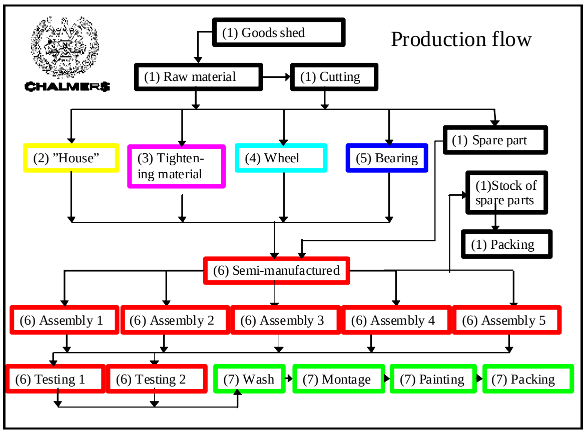

Figure 5: The production flow divided into seven production units

The project was coordinated in a activity organisation with eight groups and nine activities see Table 1. The overall group where responsible for handling the project plan and maintain the communication channels between the seven production unit groups.

Table 1: Project organisation map

	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7	OVERALL GROUP
Problem definition								
Data collection								
Modelling								
Integration								
Verification								
Visualisation								
Validation								
Optimisation								
Planning and controlling								

The activities in Table 1 were modified from the methodology concerning steps in a simulation study described by Banks et al (2001).
From each group, at least one student was attached to each activity within the project map. Communication channels were opened both within the group and between all responsible students in each activity.

Results
Reflections from the activities were made during the project, which are highlighted and summarised below.

Problem definition: It is important to not only look upon the group's definition of the problem but also on the problem definition as a whole. This will ensure that all the parts (i.e. sub-models) of the model have the same level of detail and can work together to a wide extent. It is also important to understand what parameters to measure in the beginning, enabling preparation for the future merging of the sub-models.
Data Collection: Collecting data has in many projects been the missing link to a successful simulation project. The data is often in the wrong format or not updated and sometimes even estimated. If the right data can not be gathered initially, the model has to be checked carefully in the validation phase and also be analysed for its sensitivity to other input data.
Modelling: In this phase it is very important to have good communication between the developers to reduce sub-optimisation, and to solve complex modelling tasks. Building up a network between the developers will also improve creativity within the problem solving phase, where solutions can be used by all developers. Modelling takes time, but there were groups that got more attached to their model and adding more details than needed to solve the problem.
Verification: Since the main model was updated by each group at short intervals the verification was not expressed as a problem.
Visualisation: Machines and factory layout were given 3D-life in a low level of detail. This phase was done mainly to make the personnel at the company understand the model more easily, and find acceptance for the model as a replication of their company.
Validation: This phase of the project was left out to be conducted by the company after a takeover of the model.
Optimisation: This phase was also left out from the project course.
Planning and controlling: Many of the groups addressed problems with integrating the sub-models as the most difficult one. This phase should have been started earlier in the project. All groups had an own project room situated close to each other in a laboratory which enabled good communication environment. Even so, there was still a lack of communication between certain groups. The closeness between the groups that the project room created made all groups work nearly the same amount of time in the project, which was appreciated by the students.

CASE STUDY REFLECTIONS TO VE ENVIRONMENT

The case study was conducted at one single company, which in other words is not a VE. In a VE the production system is more complex, with a less hierarchical structure, compared to a single company. Still the case study was handled in a manner that would suit a structure of a simulation study on a VE environment with production units representing small companies. Each student group represents one company in the VE, focusing on one area, unaware of the companies hierarchical structure. By using incremental development method the multiple developers worked in a way which made it representative to a VE environment. From the case study only reflections are made, due to the complexity that VE models have which will make conclusions hard to draw. The DES software used in the case hade not, in this version, a support for handling hierarchical models which would have simplified the case.

DISCUSSION AND CONCLUSION

This paper gives rise to reflections of important issues when carrying out a Discrete Event Simulation project with multiple developers. The reflections after the case study were:

- It is of vital importance to start with integration as early as possible
- Many meetings with divided goals and result follow-up are needed
- Clear project goals for the model building as a whole are important
- Communication in general has to be extremely frequent to achieve success

Communication was not seen as a major problem which, according to the groups, was due to the nearness of the groups during the project, and the fact that the group members already know each other. However there were some problems with communication when it came to knowledge about the model and the real system, which caused misunderstandings and rework. Also sub-optimisations indicates that communication between the groups in each activity was not sufficient. Additionally communication is of importance due to the distance between companies in a real VE, which was not reflected in this study. Transferring knowledge between developers is a research area in it self (Nonaka, 1994) and communication is the way of sharing this. To secure communication during the project a clear organisation and methodology has to be applied, like the activity organisation used in the case study.

The groups' found it hard to schedule the activities during the project which indicates the importance of making all participants understanding and accepting the objectives of the model. Once again communication is an important issue.

Building simulation models is an art and when multiple developers are involved there is an increasing need of starting in a small and simple way (Keep It Small and Simple). This will simplify the verification, which in complex models like VE environment is very hard. Integration is the hardest phase in these kinds of simulations and therefore it is important to let the model grow as a whole from the beginning of the project, and not as islands.

Working efficiently with DES in a VE environment, compared to a traditional company environment, has to be more focused on synchronising and standardising the model building. This would make it possible to "plug and play" models together when a new VE constellation is to be analysed.
A Virtual Enterprise that competes with larger companies does not have the same amount of supporting tools for making improvements within the production process. When working with Discrete Event Simulation as a decision tool, a Virtual Enterprise has larger potential in improving the competitiveness of the divided production system.

Future of VE simulation

Building simulation models that is valid to the real production is hard work not least because the lack of accurate data (Johnsson and Johansson, 2003). This lack may soon occur to be a problem of the past due to the increased number of computers that are attached to machines nowadays (Taylor et al, 2002). Taylor et al also states that the tremendous potential that distributed simulation has can fall on the willingness to share sensitive/critical data.

Simulation software have become more and more object oriented with an hierarchical thinking that supports a easier handling of VE models. Models will not be merged in the future, which will make naming convention an issue of the past. Pegden predict that future software could handle pre-built models or model component that can be plugged together to form a model of our system (Diomond et al, 2002). This future looks bright.

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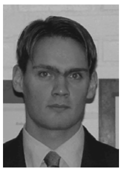

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