JOINT SIMULATION MODELING TO SUPPORT STRATEGIC DECISION-MAKING PROCESSES

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ABSTRACT
The airfreight industry is highly dynamic. Airline companies need to adapt their processes continuously. This case study was carried out to support an airline company in designing a strategy for airfreight handling. The goal of our research was to explore the operational implications of strategic decisions on the new structure of airfreight handling processes. A Collaborative Business Engineering approach was followed in which simulation models were constructed jointly with the management of the airline company. Simulation models of the freight handling processes were built to provide insight in alternative designs of warehouses. Base models were constructed to save time during the joint modeling sessions. During the group sessions the base models were adapted and expanded jointly with the management. After the group sessions extensive experiments were conducted and the results were presented to the management. The CBE approach was applied successfully. The simulation models and results were valued highly by the management. The management had high levels of trust in the models because of the joint modeling and the 3D animations. In the end the management was able to study a 'richer' set of alternatives; more alternatives and more detailed insight in each alternative was gained.

1. INTRODUCTION
Our research was carried out for a large airline company in the Netherlands, which participates in one of the leading global airline consortiums as an independent European partner. The airline company transports more than 15,7 million passengers and 621,000 tons of cargo and mail. Their route network connects 145 cities in 67 countries. The cargo-flights use the home-airport as a hub, which is a central point for all flights. The passenger and cargo flows have increased strongly in the last years. The home airport developed plans to restructure and expand at the time of our research. This forced the management of the airline company to think about the future airfreight handling processes. This research was started to provide the management insight into future alternatives for cargo handling, e.g. designs and locations of new warehouses, and new freight handling procedures.

The design of airfreight handling processes is a complex activity. The problem setting is characterized by a large design space. A large number of degrees of freedom on several axes exists; a lot of actors are involved, many technological questions have to be answered, and a lot of uncertainties have to be dealt with (Babeliowsky 1997). Among the actors are airport authorities, central and local government, freight handlers, airline consortium partners, and customs. Each actor has its own goals and objectives, which are frequently conflicting. This leads to a complex multi-actor setting and an intransitive problem setting, where it is impossible to select a single alternative that is preferred to all other alternatives (Dunn 1981). The actors make their own decisions that cannot be influenced by the airline company. Such decisions, however, influence the freight handling processes, e.g. regulations of the airport authorities. The problem is technical complex. The possibilities of automated airfreight handling have to be taken into account, due to the relative high labor costs in the Netherlands. The airline company has to deal with a large number of uncertainties in economic developments. The prices of freight transport and transported volumes are dynamic and influence the design of the warehouses. After September 11th 2001 the security regulations have been increased. This has severe consequences on the freight handling processes; freight is thoroughly checked before flights.

Due to the complex problem setting there is little consensus on the new structure of the airfreight handling processes within the management. The goal of our research is *to provide the management insight into possibilities and limitations of new structures for airfreight handling*, at current and alternative locations, given growing cargo flows and restructuring of the home airport. We followed a Collaborative Business Engineering approach supported by simulation.

After this introduction the Collaborative Business Engineering is discussed in section two. Our Collaborative Business Engineering approach,

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abbreviated to CBE, supported by simulation is presented in section three. The case study in which the CBE approach was applied is presented in section four. Section five presents some lessons learned during the case study. This paper ends with a number of general conclusions.

2. COLLABORATIVE BUSINESS ENGINEERING

Modern organizations face an almost constant need to evaluate their strategies, processes, and systems (Drucker 1988, Hammer 1990, Davenport 1994). Organizations continually have to adapt to changes in their environment, such as new legislations, new partners and changed market demands. Meanwhile organizations must satisfy continuous increasing internal demands with respect to operating more efficient and more effective. Organizations can apply the principles of Business Engineering in order to deal with these issues. Business Engineering is "organizational transformation focusing on integral design of information technology, organizational processes, and structures" (Hammer 1990). A number of different Business Engineering approaches have been presented during the last years (see for an overview Meel 1994). In general, BE approaches are not suited to facilitate multi-actor settings. Our problem area, the airfreight industry, is characterized by a multi-actor setting (Babeliowsky 1997). We extend Business Engineering to a Collaborative Business Engineering approach supported by simulation (Maghnouji & Versteegt 2003). Collaboration is the process in which two or more individuals with complementary skills interact to create a shared understanding that none had previously possessed or could have come to on their own (Schrage 1990).

We expect that by applying the CBE approach decision-making processes will be more efficient and effective. The lead-times will be decreased (efficient) and the outcomes of the decision-making process will be supported by all actors involved (effective). Actors in intra- or multi-organizational settings have conflicting objectives. All actors want to make sure their points of view are represented in the design and that the design satisfies their interests. Integral solutions are needed in this multi-actor setting.

To reach an integral solution actors need a common frame of reference, a shared space (Schrage 1990, Senge 1994). If the shared space is not created, actors will keep living in their "own world" and communication will be impaired making it very difficult to reach integral solutions. Within complex design processes humans are conflicted with bounded rationality (Simon 1969). There are practical limits to human rationality, which makes it hard or even impossible to find an optimal solution. By following the CBE approach we limit the effects of bounded rationality by combining knowledge and skills of actors from different disciplines. The CBE approach does not lead to an optimal solution, but to an integral solution; one that satisfies involved actors. Crucial aspect of the CBE approach is a shared space of understanding. *Within the CBE approach we develop a shared space of understanding by jointly constructing simulation models*. The models are projected on a central screen, visualizing the shared space of understanding. "Tacit" mental models of each participating actor are made explicit in simulation models to support discussions. Simulation offers other advantages. Simulation is used to study the operational aspects of a system. By working on the operational level design choices appear that would have been overlooked otherwise. The ability to work in a quantitative way on the operational level enhances the process of strategic decision-making. Simulation also offers possibilities to compare different designs of the airfreight handling processes.

Traditional approaches to simulation studies are iterative processes that contain the following steps: problem formulation, setting of objectives, model conceptualization, data collection, building of the model, verification, validation, experimental design, model runs and analysis, documentation and reporting (Law & Kelton 1991, Banks 1998, Zeigler 2000). Traditional simulation approaches are not suited for joint simulation modeling. First, traditional simulation approaches have long throughput times. During joint simulation sessions there is only limited time available. Managers lack time and can only spend little time in group sessions. Second, in traditional approaches model builders construct the simulation model mostly on their own. In joint simulation modeling the model is build together with the problem owner. Traditionally problem owners are only little involved in constructing simulation models, they provide the boundaries, and questions that the models needs to answer. In joint simulation modeling the problem owners are participating actively in constructing simulation models. During joint modeling sessions laymen are involved in constructing simulation models. The problem owners are not familiar with simulation. A number of elementary simulation principles have to be explained to laymen. The problem owner has to make model assumptions and decisions about detailed aspects of each alternative during the group sessions. This enables the actors to gain shared understanding in all aspects of the alternatives. Third, in traditional simulation approaches there is a lot of time available for data collection. During group sessions data has to be available directly. Not all data can be obtained directly; assumptions have to be made. Fourth, traditional simulation requires large a number of model runs for obtaining reliable statistical output. During group sessions there is no time available for long simulation runs. It is more important to gain rough insight into the alternatives. Short model runs are needed.

3. CBE APPROACH SUPPORTED BY SIMULATION

We develop a Collaborative Business Engineering approach in which simulation is used as a supporting tool. It consists of three phases; preparation, joint-simulation modeling sessions and presentation of the results, see figure 1.

Three different types of actors are involved in the CBE approach, facilitator, model builder and problem owner. The facilitator supervises the CBE process. The facilitator has knowledge of group design processes and guides the group in efficient decision-making. The facilitator structures the activities and secures the progress of each activity. The facilitator supports the decision-making process, without intervening in the actual content of the process. The model builders are responsible for constructing the simulation models. The problem owners define the problem definition, the model requirements and the evaluation criteria and provide input during the joint modeling sessions. This input ranges from small details, for instance the speed of a fork lift, to totally new designs.

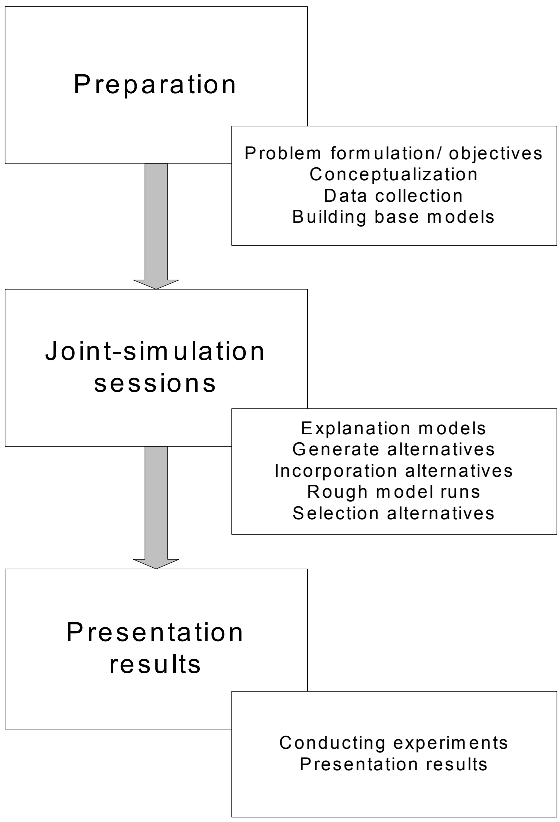

Figure 1. Collaborative Business Engineering Approach

In the first phase, *preparations*, the preparations for joint-simulation modeling sessions are made. Good preparations are crucial, since the available time for the joint modeling sessions is limited. Managers have little time available and it is hard to bring them all together for a long time. Many time-consuming activities are performed before the joint modeling sessions, e.g. data collection. In the preparation phase the first steps of the traditional simulation approach are performed; the problem formulation, the clarification of the objectives, the conceptualization of the problem and the data collection of the basic processes. This requires time because different members of the problem owner may all have their own view on the design problem. These views must converge first before the joint modeling sessions can start. The facilitator is responsible for this process. The base models are constructed. Base models are simulation models that will be used as starting points in the joint-modeling sessions in the second phase. Base models are needed because it is impossible to construct a complete model from scratch within a joint-modeling session due to time limitations. One of the base models is the status quo model, which describes the current situation. This will be used to establish the shared space of understanding. Other base models should contain elements that are either expected not to change during the joint sessions (for example static objects such as buildings or railways) or that are impossible to model in a short time (for example control logic).

The goal of the second phase, *joint-simulation sessions*, is to jointly generate and evaluate alternatives. In the second phase the base models are explained in depth to the problem owner. The problem owners generate large numbers of alternatives by studying the base models. The facilitator encourages this creative process and structures it. The alternatives have to be incorporated in the base models. During group sessions the model builders and problem owner jointly create new simulation models. The problem owners generate alternatives, while the model builders construct models of these alternatives. This forces the problem owner to specify a lot of choices in each alternative and to make assumptions on how each alternative will be modeled. After a large number of alternatives have been generated fast model runs are performed to get a rough insight of the consequences of each alternative. This enables selecting the most promising alternatives and adapting or removing less promising alternatives. This procedure is repeated several times until only the most promising alternatives remain.

The final phase, *presentation of the results*, is conducted after the joint simulation sessions. Goal of this phase is to provide the problem owner with a thorough analysis of the chosen alternatives from the joint modeling sessions. Extended simulation models of the most promising alternatives are constructed. These models are used to conduct numerous experiments to obtain statistically valid output of each alternative. This is not possible during the second phase, due to the lack of time. The results of the experiments are compared and presented to the problem owner. The responsibility for choosing one of the presented alternatives and eventually implementing this alternative lies at the problem owner. The CBE approach supports problem owners creating a number of promising alternatives, not in choosing one of the alternatives.

The CBE approach does not prescribe what simulation software to use. A number of criteria are given that the simulation software has to meet. The simulation software has to provide realistic animations. This is especially important when laymen are involved. Animations create a shared space of understanding. The modelers must be able to create models quickly. During groups sessions there is only limited time for model building. The software has to be flexible. Ideas from the problem owners must be implemented quickly, without major changes in the structure of the simulation models. The simulation software has to allow modeling at different aggregation levels. The level of detail of the model should be determined by the problem owners and not by restrictions of the software.

4. CASE STUDY: AIRFREIGHT COMPANY

Phase 1: Preparation phase

At the beginning of the preparation phase the airline company provided the problem definition and the research objectives. The problem definition and research objectives were too broad and ambiguous. The problem definition and objectives had to be sharpened in order to be able to construct simulation models. The second step was the construction of conceptual models that define the problem situations in broad terms. The conceptualization resulted in an overview of the different types of cargo and the current structure of the airfreight handling processes. Several types of conceptual models were constructed, mainly graphically oriented, like flow diagrams and layouts of airport and warehouses. The layouts and flow diagrams were combined in order to create an overall view of the freight handling processes. The conceptual models were created in such a way that they could be easily translated into empirical simulation models. The third step was to collect data as initial input for the simulation models. The management of the airline company expressed a wish to use real-world data rather then using stochastic distributions in the simulation model. The main reason to use real-world data was the lack of confidence in stochastic distributions by the management. The arrivals patterns of planes and cargo is capricious. This makes it difficult to fit stochastic distributions from the real-world data. Collecting the real-world data led to several problems. The real-world data was retrieved from database systems containing all cargo information of the last years. The different database systems had to be merged to be able to retrieve input data for the simulation models. This was a time-consuming process, resulting in a huge database that was difficult to access and process. The final challenge was to link the database to the simulation models. In the database each line represents a single cargo load. In order to retrieve specific cargo information the simulation package has to search the database every time a cargo unit arrived in the model. Since the database was large, the search times were long, which led to performance losses of the simulation models.

The final step of the preparation phase was the building of base models. The base models were built in AutoMod version 10 (Banks 2000, Stanley 2001). AutoMod offers realistic automatically constructed three-dimensional animations, which is used for validation of the model. All infrastructures in AutoMod are built true-to-scale. AutoMod allows us to study the logistic processes at different levels of aggregation to study the operational aspects of freight handling. Finally, AutoMod is a package well suited for simulating logistic systems, with built-in features for Automated Guided Vehicles (AGVs), conveyors, and AS/RS (Automated Stacking and Retrieval System). All these characteristics of AutoMod are useful for simulating airfreight-handling processes.

The base models were constructed in cooperation with individual members of the management, middle management, and shop floor personnel. The different logistic systems were modeled in the base models, including layout of the airport, cargo buildings, handling procedures, infrastructure for forklifts, transporters, conveyors, trucks, planes and AS/RS. During the construction of the base models each individual component was validated directly in order to detect errors in an early stage. The validation of these components was conducted by the (middle)-management. This led to high levels of commitment and trust in the models.

Phase 2: Joint Simulation Sessions

In the second phase two joint modeling sessions took place. The goal of the first session was to create shared understanding and validate the entire base models. The goal of second session was to generate and alternative designs of the airfreight handling processes. During the group session the base models were presented to the management. Animations and results of short model runs were used to validate the models. Two types of validation were applied; structural and replicative (Sol 1982). Face validation, a form of structural validation, was applied, by animations to the management (Law & Kelton 1991). Replicative validation was applied by comparing the results of the simulation runs to real-world data and expectations of the management. This resulted in a shared understanding of the problem situation and high levels of trust in the simulation models. A Group Decision Room (Vreede 1995) was used to identity and rank the most important performance indicators during the first joint simulation session. These performance indicators were incorporated in the simulation models after the session.

The goal of the second session was to generate and study alternative designs of the airfreight handling processes. The management generated a large number of alternatives. The management was forced to make explicit choices regarding the operational aspects for each of the alternatives. This was needed for the immediate incorporation of the alternatives into the base models. Examples of such choices are the location of the warehouse, detailed specifications of forklifts and loading procedures. By making these choices the management gained detailed insight into the consequences of each alternative. During the session short model runs were made and rough simulation output was collected. Based upon the output the management selected the most promising alternatives. In the third phase these alternatives were studied in more detail.

Phase 3: Presentation results

The base models of the most promising alternatives were extended after the joint modeling sessions. During the joint modeling session a number of assumptions had been made on the alternatives, since there was no time to collect all real-world data. For example, the exact position of a new terminal, the exact number of AGVs and processing times.

The validation of the extended models was carried out by involving domain experts in the validation process, e.g. different members of the management and airport officials. More experiments with the simulation models were conducted in order to obtain reliable statistical data. These included different scenarios such as future expectations about cargo volumes.

The results of the experiments were compared and presented to the management. The responsibility to choose the most satisfying alternative is no part of the CBE approach and was therefore left to the management.

Using the CBE approach the management was able to choose an integral strategy for airfreight handling processes for the next decades that was supported by all members of the management.

5. LESSONS LEARNED

Simulation has a number of limitations for supporting Collaborative Business Engineering approaches. Constructing simulation models during sessions based on on-line input, conducting experiments, and use results directly for further exploration was not entirely possible. Constructing, debugging, and validating simulation models takes too much time during group sessions.

The preparation phase before the group sessions proved to be vital. During the preparation phase several base models were constructed to shorten the construction time during the group sessions. During group sessions changes to the base models were made and short experiments were conducted. After the group sessions the models were validated and more and longer experiments were conducted. The base models shortened the construction time during the group sessions, however, there are limitations to the flexibility that current simulation software offers. Not all changes could easily and quickly be incorporated in the base models. Changes to the infrastructure could easily be made. Changes to the control systems could not be incorporated during the sessions. The control systems consist of complex control algorithms that were difficult to understand for the management and difficult to validate during the sessions. For constructing base models it is important that clear problem definition and research objectives are available. This way the simulation model builders have a good idea on the type of base models they need to construct before the joint modeling sessions.

The simulation results during the group sessions formed a good starting point for discussions among the different members of the management. The simulation models forced members to make explicit choices and assumptions on the design of the airfreight handling structure. The members were forced to make their thoughts explicit and discussing such choices led to a shared understanding of the problem situation. Simulation supported the communication between members of management during these interactive sessions and smoothed and sped-up the design process. Changes to the base models were made while the management could look at the simulations models. This joint modeling sessions led to high levels of trust in simulation models and simulation results by the management.

The problem formulation and objectives changed during the project. The management came up with new ideas and whishes for the simulation models as they gained new insight during the project. This was difficult for the model builders, the base models had to be adapted frequently during the entire CBE approach.

Animations derived from the simulation models created a shared space of understanding within the management. Three-Dimensional true-to-scale animations were made of the warehouse and parts of the airport, as can be seen in Figure 2. Animations were used to validate the simulation models. The animations led to high levels of trust in the simulation models and simulation results. Animations were not used for decision-making during the group sessions. The management used traditional figures and business graphs to make decisions on the new structure of airfreight handling.

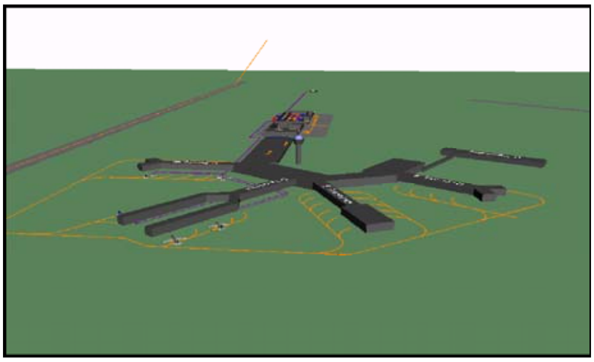

Figure 2. Animation model of airport

The project of designing new structures of airfreight handling was continued by the airline company after this research was finished. Our research had two positive side effects for the airline company. First, the airline company started to make more use of simulation as a modeling tool. New simulation models were constructed of the airfreight handling processes in the next phase of the design project. The new models are based on the simulation models that were developed in the joint modeling sessions. Second, the airline company was forced to spend a lot of time on data collection. This resulted in taking a close look at all the available data of the airline company. Several separate databases were joined in one Management Information System, which improved data collection of the airfreight handling processes.

6. CONCLUSIONS

The CBE approach resulted in a 'richer' decision-making process. The management came up with alternatives that otherwise would not have been taken into account. The simulation models that were created during group sessions led to a shared space of understanding of the problem situation and alternatives. The CBE approach supported by simulation allowed the management to study more alternatives and to study each alternative in more detail. This provided the management the necessary insights to develop an integral strategy for airfreight handling processes for the next decades. The joint simulation sessions led to high levels of trust in the simulation models and simulation results. The alternative that was chosen in the end was supported by all members of the management.

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