Collaborative Simulation Modeling: Experiences and Lessons Learned

R. Maghnouji, G.J. de Vreede, A. Verbraeck, H.G. Sol
Faculty of Technology, Policy and Management
Delft University of Technology
P.O. Box 5015 – 2600 GA Delft
The Netherlands
{rachidm, gertjanv}@sepa.tudelft.nl

Abstract

In this paper experiences with a collaborative design approach, supported by discrete event simulation are presented. Four studies, in which alternative designs of organizational processes are explored, are discussed. One study takes place at an insurance company and three at an airport. The way of working followed, is evaluated and compared to the existing problem solving approach, which represents a tradition of collaborative business engineering. Furthermore the collaborative aspect and the simulation support are evaluated, in order to come with improvements for the participative way of working and its support.

1. Introduction

Modern organizations face an almost constant need to (re-)evaluate their strategy, processes, and systems [5, 8, 12]. Organizations have to adapt to new external demands from their markets, while satisfying internal demands with respect to operating more efficiently and cost-effectively. Over the last decade, a considerable number of business engineering approaches have been presented (see e.g. [18] for an overview). Business Engineering has been defined as "organizational transformation focusing on integral design of both information technology and organizational processes and structures (12, 4, 18). The research tradition to be presented here follows a collaborative dynamic modeling approach to support business engineering. Discrete event simulation and a Group Support System (GSS) are used in this approach, which will be called from now on: "The Collaborative Business Engineering approach," abbreviated to CBE. Parts of this tradition have been used successfully in a number of projects, see e.g. [1, 9, 11, 18, 24, 25, 28, 29).

In this paper CBE is applied to address logistical problems at both a strategic and an operational level. The situation at hand is looked into at an operational level in order to support strategic decision making. The assumption behind this is that detailed insight in a possible design is gained, which results in a better evaluation of alternative designs, as participants are confronted with design choices at an operational level. These choices would not have emerged if the design was made at a higher level of abstraction. This operational detail makes discussion on the situation more tangible and boosts trust in a resulting design.

The CBE approach can have two starting points:

It can start with a problem that has to be solved. First a conceptual model is made of this situation and then an empirical model, which is in many cases a discrete event simulation model. This empirical model supports the evaluation of previously generated alternative solutions for the problem. For a detailed description see [30, 31].

It can start with an opportunity that has to be explored and transformed into a design. In this case a different way of working is followed, which will be discussed in this paper. Characteristic for this way of working is that alternatives of the opportunity are generated and visualized at the beginning. The interesting alternatives are then modeled for testing and evaluation purposes.

Previous studies in the field of CBE have shown that participation is important for various reasons. It leads to getting commitment from the participants, gaining better understanding of the participants' work and creating shared understanding [22, 23, 30]. Furthermore, model development time and design time can be cut as information is gathered in a shorter time than in the case of bilateral information gathering [30]. Participation has to be managed in an efficient and effective way as participants have limited time and projects have tighter deadlines. This poses requirements on the support needed for collaborative design sessions as part of a way of working.

Fast modeling: stakeholders do not have time to sit through lengthy modeling sessions.

Interactive design supported by models: participants are brought together for interacting with each other, this interactivity has to be supported by the models used. This may mean that several models have to be prepared beforehand or that it has to be possible to build and/or modify models on the spot.

0-7695-0981-9/01 $10.00 (c) 2001 IEEE

Effective modeling: stakeholders must understand the situation they depict without much effort.

The focus of the study presented in this paper is to explore a way of working, modeling techniques, group modeling techniques and supporting tools that enable fast and effective group participation in logistical organizational design. This deals with designing organizational primary processes, where a logistical view is leading. In this paper, in particular the support of the design process by discrete event simulation will be looked into. This exploration is based on the results of four cases.

2. Background

2.1. Earlier research on CBE approaches

Little research has been done in the area of collaborative business engineering, where modeling is crucial. Dennis et al [7], Dean et al. [6], Pendergast [20] and Lee et al. [16] have reported on group model building supported by GSS, where organizational processes were conceptually modeled in IDEF0. These studies suggest that GSS speed up the process of conceptual modeling and enhance the model quality. A major problem remaining, is the integration of the models made by the different subgroups. This converging task seems difficult to support by a GSS.

Group mental mapping is also an area, where among others causal maps are developed with a group; see e.g. Eden and Ackerman [10]. Mental mapping can be used for eliciting perceived problems of the actors involved in a problem situation. Furthermore, Vennix [26], Richardson and Andersen [21] and Vennix and Akkermans [27] deal with causal diagramming and continuous simulation with groups. An important contribution from their research is a description of the components of group model building sessions and of the needed roles in such sessions. This research suggests that the conceptual causal maps or cognitive maps have more added value for the participants, than the quantitative version of these models. The subjective character of these models makes it difficult to forecast future behavior on a quantitative basis. The models are more vehicles for group discussions and for eliciting mental models, which is where the added value lies for the participants. The difficulty of integrating sub-models of different participants or groups is also observed here.

Collaboration research is important for the research presented in this paper. In particular the notions of shared space and shared understanding. Shared understanding is a result of collaboration as can be seen in the definition of Schrage [22]: "Collaboration is the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own." Important conditions for collaboration are: mutual respect and trust, the creation and manipulation of a shared space, learning by playing with representations and continuous but not continual communication [22]. Continual communication can be defined as communication when needed and on a regular basis instead of forced communication every day for example. The shared space is needed for making the "tacit" mental models of the participants explicit in order to support discussion [23].

2.2. Description of CBE

The CBE process consists of a number of basic design activities. The order and extensiveness of the activities depend on the type of project, i.e. is it a problem to be solved or an opportunity to be explored? It also depends on the bandwidth of the project, where bandwidth is defined as the number of degrees of freedom of a problem or an opportunity. This is determined by:

The scope of the problem or opportunity: is it narrowly defined or is it open?

The existing amount of insight in the problem or opportunity: is it clear or vague to the participants? Here it has to be mentioned that individual insight may not be at the same level as the shared group insight.

The basic design activities, which are not necessarily executed in a chronological order, are:

- Delineate the problem or opportunity
- Define project boundaries
- Gather data (both conceptual and empirical)
- Formulate requirements to be posed on the design.
- Generate alternative solutions or designs
- Build and validate a discrete event simulation model
- Evaluate the results
- Converge from several alternatives to a few

These activities may be supported by several tools:

Discrete event simulation and animation tools (e.g. Arena 3.0 and Simple ++), which use templates and libraries to cut the modeling time.

Group Support Systems (e.g. GroupSystems for Windows) to support group discussions during model building and model use activities.

Sketching, physical scale models and animation are used to visualize the situation and to create a shared space for group interaction.

For a detailed description of the way of working in the case of a problem situation we refer to [30], which also indicates which activities have to be done with a group and which not. The group activities are led by a facilitator, who determines for a major part the group process [26].

This paper will focus on a number of case situations in which opportunities had to be explored. In these cases, the same design activities were carried out as in problem solving projects, but in another order and level of detail. Our discussion below will be focused on one particular supporting tool: discrete event simulation modeling. The new way of working for opportunity exploration that emerged during the case studies will be presented after the cases themselves in section 5.

3. Research Method

During the study presented in this paper, we employed an action research approach as the phenomenon at hand was considered too complex to be studied in a constructed setting. Action research involves the application of tools and methods to practical problems with the dual intentions of improving the practice and contributing to theory and knowledge [15, 3].

The study comprises of four case situations in which simulation models were constructed, validated and used to explore opportunities for organizational redesign. The cases were selected based on the serious nature of the problem at hand (we only included "real" problem situations in the study) and willingness of the involved organizations to participate in activities that served research goals, such as post-session interviews.

During the case studies, notes were kept by all researchers involved. We compared these notes and looked for common themes and insights. Moreover, we carried out informal interviews with all problem owners and a random selection of session participants. These interviews addressed various issues, including trust in the results, the factors this trust is based on, the required representation of the results, understandability of the model, insight in the modeled situation, and commitment to the results. After analysis of our data, key insights were presented and checked with problem owners for validation purposes.

The role of researchers in the case studies was multifaceted. We supported the problem owners in the case situations by constructing and running simulation models. Moreover, we facilitated the design sessions during each case. Our interventions were exclusively focused on supporting the problem owners' design process and subsequently learning from that. We had no personal stake in any of the problem situations or opportunities that were to be explored.

4. Results

Four studies will be described, one study was carried out at an insurance company, two at an airport and one at an airline. From each study the problem at hand, the process and the findings will be described.

4.1. The Insurance Company Study

4.1.1. Problem. The first study was carried out at a department of a big insurance company in the Netherlands, which investigates insurance claims. The department is subdivided in clusters of experts with the same expertise, e.g. fire, automobiles, and health. The primary process of the department and the experts consists of the following steps:

Claims come in and are distributed over available experts,

The expert makes an appointment with the insured person or company,

The expert plans his driving route and pays the insured one or more visits,

The expert finally makes a report with an advise whether to pay or not.

The problem faced by the department was lack of insight in the performance of the department. Kaplan and Norton [14] suggest the Balanced Scorecard as a measurement system for the total business. By developing a Balanced Scorecard the department got a feeling of the success factors they thought important, see [17]. The next step was to quantify these important success factors and to explore possible solutions for problems using discrete event simulation. Examples of questions are: how much time can be saved if an expert does not have to make appointments himself, should the expert himself plan his visits or should it be done centrally for all experts, how much travelling time is reduced if small claims are paid without investigation and how is the workload of experts in a certain cluster compared to other clusters?

4.1.2. Process. First the participants were chosen depending on their contribution to the simulation project to come. Input experts, decision makers, process owners and modeling experts were invited for the first session, the kick-off meeting. The following questions were on the agenda:

- Which questions have to be answered, which opportunities should be looked into?
- Which alternative organizational forms can these opportunities have?
- Which output variables should be used for evaluation of the solutions?
- What does the primary process of the insurance experts look like?

In the second session the input for the simulation model was defined based on findings from the first session. For this session participants were invited with knowledge of available data at the insurance company. The results of this session were taken by the modeler at the end of the session for building a first simple model with little detail, but with the model skeleton. This was used in the third session, in which the model was explained to the process owners (insurance experts) and refined with their comments. Work intensive parts of the modeling process were completed outside the group sessions and in the last session the running model with animation was validated by process owners of the insurance company. The simulation results and the animation were presented to the department managers, who were enthusiastic about the insight they gained and the confirmation of insight they implicitly already had. The model building process and the model made several problems clear and revealed strategic choices and opportunities.

4.1.3. Findings.

Process

Defining input for the simulation model at the start enabled concurrent data gathering, while the model was built in the meantime. In this way the time consuming activity of data gathering did not cause any delays.

During the session and the model building process a secretary role emerged for documenting the modeling decisions and assumptions made.

The model builder also had the role of facilitator. This made it very difficult to adjust the model and facilitate the session concurrently. Splitting these roles could have saved time in the second session, where a facilitator could have gathered input variables with the group while the model builder was building or refining the model.

Collaboration

Involvement of process owners in the simulation model building process appears to boost trust in the model and acceptance of the results.

A visual shared space during the model building sessions supported discussion on the working process of experts and the model. The simulation software (Arena 3.0) uses building blocks which are easy to understand for non-simulation experts. The participants did understand the structure of the model after explanation and made suggestions for improvement at moments the model did not seem realistic anymore.

Simulation

In the simulation model checks for errors were built in. E.g. a signal was given if an assignment was not distributed to an expert. These checks made the model verification easier.

All variables that have to be adjustable were put into input files. In this way the variables could be adjusted easily outside the simulation model.

The animation supported the validation process very strongly as experts from the field easily recognized the model situation and could compare the model behavior with the real behavior.

4.2. The Central Security Study at the Airport

4.2.1. Problem. When departing from Amsterdam Airport Schiphol (AAS) as a passenger you first encounter the passport check and eventually after having spent some time shopping in the lounge you will head for the gate, where the security check takes place. As these security checks take place at many gates, the airport wanted to explore the idea of centralizing the security checks mainly in order to save personnel expenses. Where should the central security check take place and what should it look like? Parties involved in this case were the airlines, the border police and the airport. The Airport was actively involved in the model building process, as they were the "problem owners." In this study possibilities of interactive group design sessions with support of simulation were explored.

4.2.2. Process. In a first informal meeting with only the airport, the assignment was explained and questions to be answered by the project were defined. In order to answer these questions, a simulation model in Simple++ was made, using an airport simulation library, which was available from another project. Before building the simulation model, project specific building blocks for security and passport check were built and added to the generic airport simulation library, in which two building blocks play an important role: Area, representing a physical surface with a capacity and Group, representing a group of passengers, who can walk or stay in an area. Furthermore, groups of passengers follow a script representing activities in a chronological order they have to perform and places they have to go to. The Airport Simulation Library is object oriented, with characteristics like inheritance, generalizations and hierarchy. This makes for example reuse of generic objects possible. The term building block is used here for objects, that can be used several times in a model, like bricks for a house. The model building was done by two model builders with knowledge of airports, one preparing the building blocks and one building the simulation model.

For the first group session three participants from the airport were invited: two with a clear view on border control and security processes and one participant with a logistics and simulation background. It was decided by the airport to involve the most important airline and the border police at a later moment when the simulation results were ready. The argument behind this is that these external parties should not be bothered by model building.

In this first session the project specific building blocks were validated. It was e.g. checked whether a security lane did have realistic behavior. This validation was based mainly on output data and slightly on basic animation. Animation in Simple++ was laborious and the only animation used, was that the building block "Area" changed color depending on the filling up of the area with passengers. It turned out that too few detailed empirical data were available for validation. This led to making the building blocks less detailed. Furthermore in this session an attempt was made to define more specific design questions to be answered by the simulation model.

To give insight in possible alternatives, a physical scale model of the airport lay out was used with security lanes and border control desks in 2-D and on scale. As a result, the number of design alternatives was reduced because many alternatives turned out to be unrealistic. After this session, the model builder simulated several alternatives and put the results into graphs.

In order to get commitment from the border police and the airlines involved, they were invited for the second session. The goal of this session was to interactively simulate and design new alternatives based on the simulation results. This goal was not reached as most of the time the evaluation criteria and in particular their targets were discussed. Defining the criteria beforehand was not the problem, but defining the targets for criteria was. The reason behind this is that the parties did not want to commit themselves to any target, which were the coins in a negotiating process. The simulation results were not what the participants expected, so they looked for ways to invalidate them. The data used and the model assumptions were checked and resulted in the decision to refine the building blocks and the model. It turned out that empirical data needed for the refinements were not available and that gathering them would take much time. This led to initialization of a new project to gather the data and refine the model. Hence, in this case with different actors, with different views, targets and requirements, it turned out that the political game was more important than the simulation, especially since validated simulation results were not used for the final decision making.

4.2.3. Findings.

Process

Defining evaluation criteria before the design is not a problem in a political arena with parties with different and conflicting requirements, but defining the targets is. Participants do not want to commit themselves to targets before they see the design and the simulation results. The targets are also part of the negotiation between involved parties about different alternatives.

Collaboration

In this study an unsuccessful attempt was made to collaboratively design new situations and simulate them. This failure had a number of reasons. First, the building blocks were thought to be validated by the model builders, but the participants wanted to validate the blocks themselves. There was no trust in the simulation building blocks. Second, based on a general design question a design had to be made. This turned out to be very difficult, as it was too unfocused. For this reason, more specific design questions had to be defined first.

The project organization with an internal and an external team worked well. The internal team did the preparation and kept the pace in the project. The external team consisted of other parties than the airport, which had their own interests. Several issues like the evaluation criteria and the definition of project boundaries had to be negotiated. This means that it will be difficult to reach an agreement on the content of these issues in the beginning of the project. The opinion of the parties depends on whether an alternative design meets their interests.

Simulation

One person preparing the building blocks and one using them to build a simulation model did not work as many assumptions in the building blocks remained implicit and led to unwanted behavior. The building blocks and the assumptions should be transparent.

If several parties are involved and have to collaborate and political issues play a role, simulation has a limited added value to the design or decision. In this case simulation is a vehicle for discussion and the results of the discussion outweigh the simulation results.

4.3. The Lounge Expansion Study at the Airport

4.3.1. Problem. Changing airline alliances and changing relations with airlines made the Amsterdam Airport Schiphol rethink their existing terminal design. In this study two possible future designs of one of the three lounges had to be explored. Questions asked were: how wide should the various passage ways be? How many security lanes and border control desks should be placed at what points? How many passengers will be in the lounge in a certain hour? How many buses are needed for transport from and to a disconnected gate?

4.3.2. Process. This project was conducted without the involvement of the major airline and the border police. In the first session the simulation assignment was explained by using sketches and maps of the airport. Two persons from the airport and the model builder participated in this first session. The model builder did have enough background to interpret the information and make a document with the situation to be modeled, the desired output, the needed input and model assumptions and reductions. In a second session this document was discussed and data gathering by the airport was started. Reusing the simulation model and the airport simulation library from the former study a new model was built to explore and evaluate the two scenarios. After the model had been built, it was demonstrated in the third session and model assumptions were discussed. The model was improved and in the fourth session it was validated, which was extremely difficult as the expectation of the participants of the future situation did not match the simulation results. The questions to be answered were, in spite of the long term scope of the scenarios, at a detailed and operational level in contrast to the available data which were not that detailed. These general data had to be made more specific by making many assumptions. These assumptions made it very difficult to validate the model and efforts to find bugs in the model were without result. Finally, the airport decided not to use the results because of the invalid model.

There were two major differences between this project and the former two. First, in this project most sessions took one hour, where in the other cases they took half a day. Second, the model of the former project was reused and adjusted to the new situation, instead of building a model from scratch with the basic airport building blocks.

4.3.3. Findings.

Process

This project started as one of the fastest as in two weeks a working model was ready. This short time was caused by the fact that the model builder knew much about the airport processes at hand and that an existing model was reused as a basis.

Collaboration

The project team was very small, which made the communication easier. Gaining trust was not easier compared to the former project, despite the fact that the participants were actively involved in the model building process.

The simulation model was a shared space between the model builder and the participants as it was used during discussions for focusing on wrong assumptions. The model builder misunderstood several issues and the participants could correct him by looking at the simulation model. This experience would suggest that the model builder should explain a model to the participants while they correct him.

Simulation

Reuse of an old model caused many problems, as many assumptions in the model remained implicit, especially the ones that were written in Simple++ code within the building blocks. Only the programmer could understand this code.

A basic model of an airport process would have been very helpful. Such a generic model would incorporate a flight generator, several airport processes at a high level, like check in, passport control and several groups with scripts. Adjusting an existing model would save time in comparison to building a model from scratch. A following question would be: use an existing model, which has to be stripped or use a basic reference model, which has to be extended? Experiences point in the direction of the latter.

Models of future scenarios are hard to validate. Participants have to trust the model and declare the model valid. Typical of the future scenarios in this project was the lack of empirical data, which makes it difficult for participants to compare model results with unavailable data.

Verification took a lot of time, as it was hard to find errors and wrong assumptions in the model. In the first project at the insurance company, verification methods were built into the model, making the bug search process easier and faster. In this case error seeking was not built into the model. Besides support for error seeking, also support for seeking wrong assumptions is needed.

4.4. The Airline Study

4.4.1. Problem. One of the most important customer-contact points of an airline is the check-in desk. A big Dutch airline wanted to explore new strategies for directing departing passengers to check in desks, which would lead eventually to a more efficient use of the check-in capacity.

4.4.2. Process. A researcher at the airline did desk research and could provide the model builders with background information. Based on this information the model builder made a first model based on the airport library from the former two studies. Two people from the airline, a data expert with knowledge of available data and a decision maker with process knowledge, were invited for the first session. In this half-day session the desired output, the different alternatives to be simulated, the needed input and the assumptions were defined and discussed. The next day the model was built and verified.

The second session was used mainly for validation and in the end several alternatives were shortly simulated and presented. During this session the model was adjusted interactively. At the end of the session the airline took the model for further exploration by themselves of different directing strategies. The total project took one week.

4.4.3. Findings.

Process

During the second session validation took most of the time. Part of the validation could have been done before the group session, as the model builders did have enough background information. It has to be mentioned that the short time of one day between the sessions was the reason that this was not done. Moreover, validation should partly be done with the group in order to establish trust in the model. Participants should get the possibility to shoot at the model, check assumptions, ask questions about it and see model results they can compare with empirical data from their daily work.

Collaboration
The interactive character of the simulation and second session led to fruitful discussions, new ideas and shared understanding.

Simulation
In this project, the simulation model clearly supported an interactive design session. Reasons for this project to be successful on this aspect are:
The simulation model was small which led to short run times, comprehensibility and easy and fast adaptability.
Hidden assumptions were avoided by building the model from scratch, instead of using parts of other models.

5. Discussion

In this chapter the findings from the case studies will be taken into account in discussing the process, the collaborative aspects, and the simulation modeling.

5.1. Process

The CBE way of working for problem solving presented in [30, 31] did not fit the explorative character of the studies presented here, which deal with opportunities. The same activities, see 2.2, are conducted, but in another sequence and with another thoroughness. Only in the first and the last study a conceptual model of the existing situation was made. Future options and possibilities were first explored and then they were placed in the existing context. The step of explicit conceptual modeling was left out in the last two studies. In three studies a start was made with exploring opportunities instead of formulating the problem.

Based on the experiences in the case studies, a number of requirements for the design process emerged. These requirements form the starting point for a different way of working in design situations where the exploration of opportunities is the key focus. Both the requirements and the proposed new way of working are presented below.

In the beginning sketches of alternative situations initiated by the opportunity play a very important role. By discussing these sketches an overview of the opportunity domain is created. This discussion also results in the first definition of the project boundaries. In the original problem solving way of working [30], alternatives are only generated later on in the process.

An important requirement to be posed on a way of working is that it cuts the project time as much as possible by performing tasks concurrently. In order to meet this requirement the sequential relationships of activities are looked into. Based on these relations and the experiences from the studies, conclusions can be drawn on the timing of activities within the way of working. One main design process can be identified, with the following activities: sketch the problem, build, validate and run the simulation model and evaluate the simulation results. Two other activities can be done concurrently to this main design process: data gathering and definition of evaluation criteria. The latter is difficult to complete early in the process, especially if the design process has a negotiation character, like in the second study. This does not imply that a start cannot be made with defining evaluation criteria. Comparatively, this activity is not time consuming, meaning that it does not necessarily have to delay the process. The activity of data gathering is time consuming and often causes delays. This activity has to be started with as early as possible in the process. To be able to do this, an “input session” with the participants has to be held. In this session first the alternatives to be simulated, the simulation output and finally the input needed have to be defined. This is done quite roughly as new insights gained later in the process can change the session results.

Several activities in the projects were performed several times. Here the distinction has to be made between iteration and evolution. Iteration: in the process a step has to be taken back and an already performed activity has to be done again because something unforeseen happened, e.g. new requirements pop up. The same activity takes place several times during the project with a changing level of depth. These refinements, which are known beforehand, can be called evolutionary. See e.g. [2].
From our case studies, it became clear that the way of working should have an evolutionary character. During the engineering process insight grows, which leads to refinement of earlier work, e.g. requirements to be posed on a design become more clear as the design gets more detailed and tangible.

As a way of working fits within a redesign project, it should also reflect project phases. Many project life cycles have been defined, for an overview see [19]. Most of these life cycles have the following four phases: Project initialization, project definition, feasibility study and design.

In the feasibility study a primarily design is made and in the design phase a detailed design is made. The latter is not dealt with in this paper. Therefore, the first three phases will be taken as a basis to describe the new way of working that emerged from our case studies.

An activity that is normally done at the beginning is the definition of evaluation criteria, which will be used for choosing the best alternative. This is difficult in a political sensitive setting, like in the second study. Committing the different parties to the evaluation criteria and their values turned out to be very difficult. The values of the norms were negotiated depending on the alternatives. This means for the way of working that the criteria can be defined at the beginning, but the criteria and in particular the norms will evolve during the project because of negotiations.

Taking all the requirements and experiences presented so far, a way of working for opportunity exploration will be derived and presented in the table below. This means a way of working which:

1. has the phases: project initialization, definition and preliminary design
2. starts with data collection as early as possible
3. incorporates the same activities several times, but in an evolutionary way
4. is supported by sketches for exploring alternatives at the beginning of the project.

Project Initialization
Sketch the situation (opportunity/problem) First exploration at a low level of detail: • Which questions can be asked given the opportunity • What is included in the project and what not • Generate and discuss alternative directions for a design • What requirements does a design have to comply with Consider who might participate in the project when Invite the selected parties (session 1) • Extend generation of and discuss several alternative directions • Define who wants to participate in which alternative direction • What requirements do they pose on a design

Project Definition
Invite the selected and interested parties (session 2) • Sketch alternative directions • These directions are at a high level, to gain insight in their merits, questions have to be posed and answered. Define those design questions. • What evaluation criteria and norms can be defined for the design • Choice of several interesting directions • Elaborate on sketches of alternative directions and make them more operational / detailed (first time). • Refine the design questions • Refine the evaluation criteria Elaborate on sketches of alternative directions and make them more operational / detailed (n^{th} time). Evaluation of alternatives and choice which to take to the preliminary design phase

Feasibility study (Preliminary design)
The chosen alternatives are simulated and evaluated. For this, simulation building blocks can be used. Two starting points can be taken here depending on whether there is a library of building blocks or not. In the first case first a library has to be built for that type of situations (branch specific). In the second case there is a library of building blocks, which can be partially used. Experiences at AAS show that often the library has to be adjusted or extended to fit the new situation / new alternatives. *Building a library from scratch:* A general library can be built before a project starts. This library might be used for different types of situations. But at the moment a project starts and the objects become clear (what issues are we talking about), the building of the specific part of library can be started. And at the moment the qualitative infrastructure becomes clear the specific building blocks can be made. *Extending a library:* The building blocks which are present have to be checked on their usability by checking the assumptions behind them. This means that every line of code in the building block has to be reviewed and checked whether it holds a sound assumption for the new situation When the simulation model is ready the alternative designs are simulated and according to the simulation results the design is adjusted and improved by the group (simulation supported group design.) This is an interactive and iterative process like the sketches in the former phases.

5.2. Collaboration

In the way of working presented above, several activities have to be performed within a group setting. Depending on the purpose of the session and on the phase of the project participants with different backgrounds are invited. The different group sessions to be held are:

- Input session(s), where an input expert is invited, as he can start as soon as possible with the time consuming activity of data gathering.
- An output specification session with a decision maker, often the problem owner, who can decide what output is needed for a decision and who can decide also on the definition of the problem boundaries.
- Model building, verification and validation session: people who have an overview of and detailed insight in the processes to be modeled. They can check during and after the model building whether the model is built according to reality, or whether assumptions and reductions made are acceptable. This leads to trust in the model and commitment to model results.
- Design session: Participants can interactively (re)design situations, simulate, evaluate and adjust them. The decision maker might also be invited for the design sessions in order to get him committed to an eventual design.

In the case of multiple parties, the roles described have to be represented by all the parties. In this case political issues play also a role, meaning that the design process has also a negotiation character. In the different sessions, time has to be reserved for these negotiations.

Several activities can be done outside the group sessions. Building blocks for the model, if not present, can already be made. Data can be gathered. The model can partly be verified and validated (replicative) and obvious alternative designs can already be implemented.

If participants have to design together, a shared space is needed. Often discussion is used for this purpose, but in order to make the discussion more tangible and visual, sketches, lay outs, maps, scale models, prototypes and animation models are used. In particular in physical design problems a physical scale model can be of great help as a shared space. Furthermore, if the simulation building blocks resemble what they represent, they can be used in the simulation for conceptual modeling purposes.

5.3. Simulation

The collaborative way of working described above can be effectively supported by simulation modeling. In order to be able to support the way of working, the simulation process should fit in the time span given. This time span is short in such design projects as can be seen in particular in the last three projects. The building and validation of the simulation model can start concurrently with the project as in the beginning results are not expected yet. After a few weeks, the simulation model has to be ready for use in design sessions. At that moment, it must be possible to adjust the model for interactive use, which means adjusting and running the model during sessions and showing the simulation results.

An important choice to be made, in the case simulation building blocks are available from earlier projects, is whether to use them or start from scratch. These are two extremes and in fact it is a continuum. The real choice to be made concerns which blocks to use and which to build. By removing the superfluous parts and adding the missing parts a total model can be used. This approach, followed in third project, had one big disadvantage: the reused model was full of non-valid assumptions, which were hidden and hard to find. If the model had been built from scratch, it would probably have taken more time, but the non-valid assumptions would probably not have been implemented. This because the model builder would have to decide explicitly on implementing or not of an assumption.

During the model building process, many problems emerged. These can be translated into requirements for simulation support for collaborative design.

In the 2nd and the 4th study we tried to make a design with the group and simulate it. Interactivity played an important role in these design sessions. This was partly supported by the simulation as building blocks were used, which could easily be changed. On the other hand running the simulation took too long and not all possibilities could be implemented. This asks for a faster and more flexible simulation. If the run time is long, a possible solution might be the following: As most alternatives are known beforehand, they can be built into the model or the steering variables can be put in a menu. In this way, changes to the model during a session can be done quickly. Sometimes runs can be done during the session, while the group is doing something else, but this is rare, as everyone waits for the results. Animation can help to make the waiting time acceptable. Another option is to get the group together more often and for a short time. This will probably raise an agenda problem for the group members.

Simulation models are often full of assumptions which are not logged, which causes a problem when used in new projects or when used by some one else than the building block builder. This was experienced in the third case were building blocks with too much detail were used, leading to hidden assumptions and an invalid model. This finding is also mentioned by Janssen et al. (2000). The assumptions have to be transparent and easy to check. A list of all assumptions is helpful to structure the verification and validation process. This list can be structured in such a way that it represents the object oriented structure of the building blocks, as an assumption in a derived object does not necessarily have to be in the parent object. A partly solution for this problem might be a library of building blocks of the same process of different levels of detail.

Results should be visual. This means animation, counters or in the worst case a quick conversion of the simulation output data into graphs. The representation form of the results depends on the background of the participants and on the type of results. Animation is not always necessary as output representation, sometimes graphs or tables are enough. Animation can be used for checking the model and as a vehicle for discussion.

In the case of different parties, a shared space which is recognizable for all participants is a must (animation in the first study, physical scale model in the second study, sketches in the third study and animation with only a signal function in the fourth study). The simulation building blocks should have a representative form, in order to make it easy for the group to comprehend the model and follow changes to the model.

5. Conclusions and further research

In this paper four case studies on collaborative simulation modeling have been presented. The four projects, one at an insurance company and three in an airport environment, dealt with exploration of alternative organizational designs. The participative approach followed has been supported by simulation. The collaborative design process is interactive with short feed back loops. A way of working was sought to support this collaborative design process by simulation. This resulted in the following experiences:

- The way of working is not the same as with traditional problem solving, generation of alternatives takes place early in the process, where sketching is an important element.
- Use of a simulation library with building blocks, which enable fast and interactive modeling, has great potential.

- In practice, many small problems have to be defeated. Examples of these problems are the speed of the simulation model, the difficult adaptability and the time consuming verification and validation process.

Based on the experiences a more appropriate way of working for projects with an explorative character has been presented and necessary group sessions have been discussed. This collaborative design process should also be supported by simulation and requirements to pose on such support have been discussed. Examples of such requirements are speed of the simulation run and model adjustments and model transparency needed for verification and for gaining trust.

The experiences presented in this paper concern refer to projects, in which alternative organizational designs were explored through collaborative simulation modeling. It is important to bear in mind that the experiences presented in this paper cannot be automatically generalized. Although the cases have much in common, they differ on several aspects like the number of parties involved, the business area, and the type of design questions asked. However, we feel that the reported experiences can serve as a basis for further improving scripts for collaboration in design sessions and effective simulation libraries. These improvements should be tested in further real life studies.

Our goal for future research concerns the development and evaluation of a collaborative design process in which simulation provides quick feedback on an alternative designs and enables the adjustment of these designs. In this way the simulation provides a simultaneous learning environment for the designers and problem owners.

References

[1] Babeliowsky, M.N.F., Designing interorganizational logistic networks a simulation based interdisciplinary approach, Doctoral Dissertation, Delft University of Technology, 1997

[2] Budde, R., Kautz, K., Kuhlenkamp, K. and Zullighoven, H., Prototyping, An Approach to evolutionary System Development, Springer Verlag, Berlin Heidelberg, 1992

[3] Checkland, P.B., Systems Thinking, Systems Practice, John Wiley and Sons, Chichester, 1981

[4] Davenport, T.H., Process Innovation. Reengineering Work through Information Technology, Harvard Business School Press, Boston, 1993.

[5] Davenport, T.H., “Saving IT’s Soul: Human-centered Information Management”, Harvard Business Review,Vol.71, No.2, 1994

[6] Dean, D.L., Orwig, R.E. and Vogel, D.R., “Facilitation Methods for use with EMS Tools to Enable Rapid Development of High Quality Business Process Models”, Proceedings of the 29th Annual HICSS, IEEE Computer Society Press, Los Alamitos, pp. 472-481, 1996

[7] Dennis, A.R., Hayes, G.S. and Daniels, R.M., “Re-engineering Business Process Modelling”, 27th Hawaii International Conference on Systems Science, IV, 244-253, 1994

[8] Drucker, P.F., “The coming of the new organization”, Harvard Business Review, Vol. 66, No. 6, 45-53, 1988

[9] Dur, R.C.J., Business Reegineering in Information Intensive Organizations, Doctoral dissertation, Delft University of Technology, 1992

[10] Eden, C. and Ackerman, F., “Strategic Options Development and Analysis (SODA) - Using a Computer to Help with the Management of Strategic Vision”, in: Doukidis, G.I., Land, F. and Miller, G. (Eds) Knowledge-based Management Support Systems, pp. 198-207, Chichester, 1989

[11] Eijck, D.T.T.van, Designing Organizational Coordination, Doctoral dissertation, Delft University of Technology, 1996.

[12] Hammer, M., “Reengineering Work: Don’t Automate, Obliterate”, In: Harvard Business Review, July/August 1990

[13] Janssen, M., Verbraeck, A. and Sol, H.G., “Agent-based Simulation for Evaluating Intermediation Roles in Electronic Commerce”, Workshop 2000: Agent-based simulation, pp. 69-74, Passau, Germany, 2000

[14] Kaplan, R.S. and Norton, D.P., “The Balanced Scorecard, measures that drive performance”, Harvard Business Review, January-February 1992

[15] Kemmis, S., “Action Research in Retrospect and Prospect”, paper presented to the annual meeting of the Australian Association for Research in Education, Sydney, November 6-9, 1980

[16] Lee, J.D., Hickey, A.M., Zhang, D., Santanen, E. and Zhou, L., “CoID SPA: A Tool for Collaborative Process Model Development”, Proceedings of the 33d Hawaii International Conference on Systems Science, 2000

[17] Maghnouji, R., Wijk, W.van and Vreede, G.J.de, “Collaborative Strategy Translation: A Critical Exploration”, in: Proceedings of the fourth Americas Conference on information Systems, Baltimore, USA, 1998.

[18] Meel, J.W.van, Dynamics in Business Engineering, Doctoral dissertation, Delft University of Technology, 1994.

[19] Morris, P.W.G., The Management of Projects, Thomas Telford Services Ltd., London, UK, 1994

[20] Pendergast, M.O., “Computer Automated Reconciliation of Activity Models for Group Supported Organizational Modeling”, Proceedings of the 30th Hawaii International Conference on Systems Science, 940-942, 1997

[21] Richardson, G.P. and Andersen, D.F., “Scripts for group model building”, System Dynamics Review, Vol. 13, Nr.2, 1997

[22] Schrage, M., Shared Minds : The New Technologies of Collaboration, Random House, New York, 1990

[23] Senge, P.M, Roberts, C., Ross, R.B., Smith, B.J. and Kleiner, A., The Fifth Discipline Fieldbook, Nicholas Brealey, London, UK, 1994

[24] Sol, H.G., Simulation in information systems development, Doctoral Disseratation, University of Groningen, 1982.

[25] Sol, H.G., Shifting boundaries in systems engineering and policy analysis, Inaugural Address, Delft University of Technology, 1992.

[26] Vennix, J.A.M., Group Model Building: Facilitating Team Learning Using System Dynamics, John Wiley and Sons, Chichester, 1997

[27] Vennix, J.A.M., Akkermans, H.A., “Clients Opinions on Group model-building, an exploratory study”, System Dynamics Review, Vol. 13, Nr.1, 1996

[28] Verbraeck, A., Developing an adaptive scheduling support environment, PhD Dissertation, Delft University of Technology, 1991

[29] Vreede, G.J.de, Facilitating Organisational Change: The Participative Application of Dynamic Modelling, published PhD Dissertation, Delft University of Technology, 1995.

[30] Vreede, G.J. de, “Collaborative Support for Design: Animated Electronic Meetings”, Journal of Management Information Systems, Vol. 14, No. 3, Winter 1997-1998, pp. 141-164.

[31] Vreede, G.J.de, Dean, D., Orwig, R., Lee, J. and Vogel, D.R., “Collaborative Design of Organizational Systems”, Proceedings of the third Americas Conference on Information Systems (AIS), Indiana, August 1997.