BUSINESS MODELING FOR NON-MODELING EXPERTS SIMULATION AND VISUALIZATION AT THE AMSTERDAM MUNICIPAL POLICE FORCE

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ABSTRACT

Business modeling is increasingly being used as supporting tool in taking important decisions, sometimes even at a frequent base. This requires that non-modeling experts are able to work with the model. Most static and dynamic modeling methods, however, are too complex for non-modeling experts to work with. The combination of visualization and simulation offers a promising means for making business models accessible to non-modeling-experts for their decision making. A simulation model of the Amsterdam Municipal Police Force was built to support managers in making decisions. Three visual modules were developed to allow non-modeling experts to work with the model without going into much detail.

1. INTRODUCTION

Decision Support Systems (DSS) as a field had appeared in the 70s. Traditional DSS were based on fundamental technologies, allowed limited communication and followed a rational approach. Most early DSS focused on presenting financial numbers to decision makers. Today's tools and technologies develop at a high rate and allow for a sophisticated support environment including simulation tools, information visualization technologies, and collaborative technologies. These developments allow decision makers not to just extract numbers and do useful calculations with them as in the traditional DSS, but also to use models to do 'what-if' analyses.

Business modeling is increasingly being used as supporting tool in taking important decisions, sometimes even at a frequent base. This requires that non-modeling experts are able to work with the model (Sterman 2000, Vreede 1997). One prerequisite for this is that the models are easy to communicate. A model, therefore, must closely resemble the mental model of the persons involved (Checkland 1981). Vreede and Verbraeck (1996) show that traditional –static– diagramming techniques, such as Entity Relationship Diagrams, Data Flow Diagrams, or SADT models do not meet this requirement. Dynamic modeling methods offer wider opportunities for understanding business processes and to analyze the process dynamics (Paul et al. 1998). Simulation is especially valuable for the evaluation of different alternatives as well as for providing statistical evidence to convince actors of the efficiency and effectiveness of a particular organizational system. However, a simulation model does not automatically resemble the mental models of the non-modeling experts. Using visualization on top of the simulation models has the potential of overcoming this problem (Vreede and Verbraeck 1996). Visualization is an essential supporting component for gaining insights and relaying knowledge (Wenzel and Jessen 2001).

Visualization offers one of the most promising means to convey information from a simulation model to decision makers in a meaningful way (Macal 2001). The goal of visualization is dependent on the phases of a simulation study and the respective target groups, for example simulation experts and decision makers (Wenzel and Jessen 2001). In this paper we look at the added value of visualization for decision makers in the different phases of a simulation study.

In the remainder of this paper, section 2 presents more background on decision making, simulation, and visualization. We present a framework grounded in literature that enables us to analyze the added value of visualization for decision makers. Then, in section 3 we use this framework in a case study. A case study was carried out at the Amsterdam Municipal Police Force to show the opportunities of visualization and simulation to allow non-modeling experts to work with business models for their decision making. In section 4, the results of the case study are presented and discussed. The paper concludes with a discussion of the findings of the study and an identification of some issues for further research.

2. BACKGROUND

Decision making is closely related to problem solving. Ackoff's (1981) definition of solving problems requires decisions to be made: "By a problem we mean a situation that satisfies three conditions. First, a decision making individual or group has alternative courses of action available. Second the choice made can have a significant effect. And, third, the decision maker has some doubt as to which alternative should be selected."

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Simon et al. (1987) described the work of making decisions and solving problems as work of choosing issues that require attention, setting goals, finding or designing suitable courses of action, and evaluating and choosing among alternative actions.

Simulation is a problem solving approach and shows many similarities with the notions on problem solving and decision making presented above. It can be used to support decision making on complex systems. Various approaches exist to conduct a simulation study. A well known approach is described by Banks et al. (2000). They distinguish the following steps: (1) problem formulation, (2) setting objectives and overall project plan, (3) model conceptualization, (4) data collection, (5) model translation, (6) verification, (7) validation, (8) experimental design, (9) runs and analysis, (10) more runs?, (11) reporting, and (12) implementation. These steps are depicted in figure 1 and described in more detail below. In contrast to most diagrams, the diagram presented in figure 1 does not put the steps on the forefront. The diagram puts main emphasis on the products resulting from the steps, since, when we talk about visualization, we talk about visualization of the products and not of the steps.

A. After the problem has been formulated (1), and the objectives are set (2), the problem situation in an organization is conceptualized (3) in order to structure the problem situation in such a way that the efforts for detailed, low-level data gathering for creating the empirical model can be focused and minimized.
B. Next, a descriptive empirical model is built that can be used to analyze and diagnose the problem situation. For this purpose, data about the problem situation is collected (4), and the model is implemented in a simulation language (5). Before the model can be used, it must be checked whether it is a good representation of the problem situation. First, the model is verified to ensure that it behaves as intended (6). Then, the model is validated to test the (statistical) correspondence between the model and the problem situation (7). If this check is passed, the empirical model can be used to identify causes and effects of the problem.
C. Based upon the results from the problem diagnosis, several alternative solutions may be generated. The alternative solutions are worked out in detail in a number of prescriptive empirical models (8). These models can be experimented with in order to study the effects of the alternatives in more detail (9). When the solutions are not satisfying enough, new alternatives can be constructed to run experiments with (10).
D. The actual choice is made based on the results of the experiments among others. This may involve a combination of possible solutions, or leaving the situation as it is. The results of the analyses are reported about (11).
E. Finally, in order to actually solve the problem situation, the solution must be implemented (12).

In a decision making process that is based on simulation, we can distinguish between several roles that communicate different knowledge about the problem simulation in different steps of a simulation study. Kuljis et al. (2001) distinguish between two roles: the analyst and the user. The analyst builds the model and works with it, the user uses the model to experiment with 'what-if' scenarios. The use of the model, however, is restricted to the use of the outcome, which is collected and presented with the assistance of a simulation expert (Kuljis et al. 2001). Vreede and Verbraeck (1996) further elaborate the role of user into the role of problem owner and the role of decision maker. The problem owner is confronted with a problem situation, but often does not have the authority

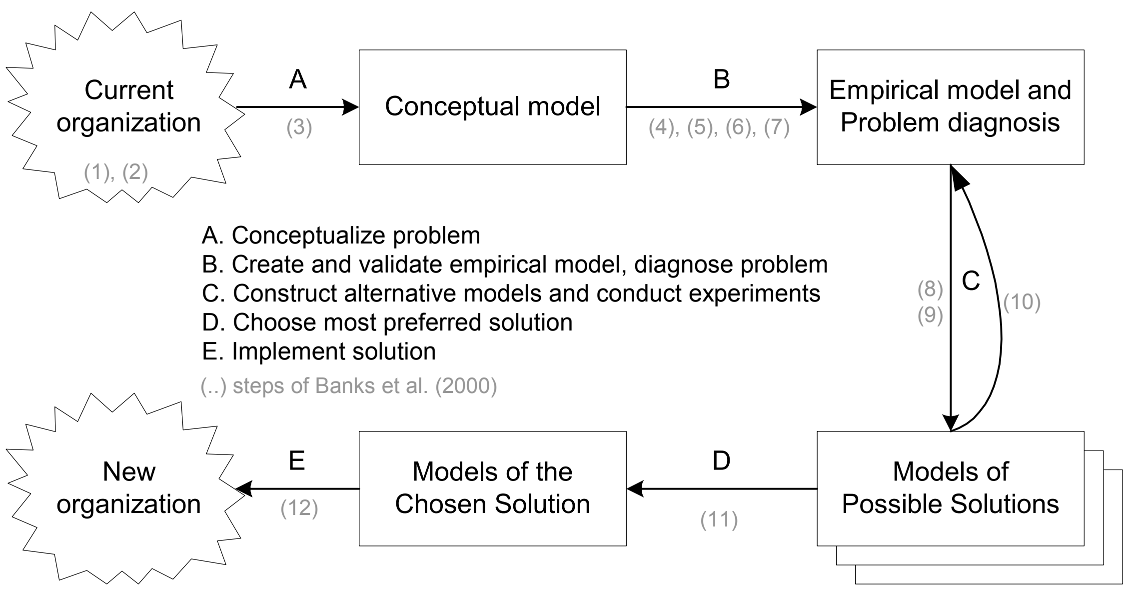

Figure 1: Approach for Decision Making in which Simulation Models are Used

to decide on changes with respect to the problem situation. The decision maker does have this authority. We distinguish between three roles: analysts, problem owners, and decision makers.

The three roles exchange information in each of the steps of a simulation study. Problem owners and decision makers communicate with each other to formulate the problem. Then the analysts enter the picture and they start to communicate with the problem owners to set the objectives, to conceptualize the problem, and to collect the data. The analysts then build the model. The problem owners and decision makers together with the analysts discuss the results of the simulation model and design alternatives. The analysts build the models for the experiments and the results are presented to the problem owners and decision makers. Finally, the decision makers decide on which alternative to implement.

In this paper we focus on the communication between the analyst on the one hand and the decision maker and the problem owner on the other hand. The analyst functions as a human interface between the simulation model and the problem owners and the decision makers. This interface would not have been necessary if the modeling knowledge of the analyst is incorporated in either the simulation tools or the problem owner and the decision maker. The latter is not an alternative, since problem owners and decision makers usually lack the modeling knowledge to complete a simulation study. Visualization has been seen as a way to support and simplify communication (Macal 2001, Vreede and Verbraeck 1996, Wenzel and Jessen 2001). Visualization as such enables to decrease the role of analyst as interface between the model and the problem owner and the decision maker. Modeling knowledge is increasingly incorporated in the simulation tool through visualization.

The use of visualization in simulation has been discussed for more than ten years. A simulation advances the state of a modeled system through time, and a visualization provides an abstract visual rendering of the state of that system at any point in time (Macal 2001). Pegden et al. (1990) state that a visualization, or animation as they call it, consists of a static part and a dynamic part. The dynamic part depicts status-changes in the simulation model and the static background represents the environment in which the simulated system exists. We follow Vreede and Verbraeck (1996) in stating that the static part represents more than the problem situation alone. It may also contain elements not present in the problem situation, like text, or static-artifacts of the simulation model, like the values of the exogenous variables. Visualization, however, encompasses more than the animation as described above. Animation depicts the results of a simulation run and puts main emphasis on the dynamic character. Visualization can also be used in the phases preceding and following the running of the model. During model construction, graphical interfaces can be used to build the model. And during the analysis of the results, statistical output of the model runs can be used for evaluation purposes.

Visualization has added value, but also limitations in enhancing communication between analysts, problem owners, and decision makers in many different ways. The enumeration below shows the limitations and advantages of visualization for each step in the simulation study with regard to communication between the different roles. These notions are summarized in the framework presented in table 1.

A. A conceptual model is a static description of the elements in a problem situation and the relationships between these elements. Two important activities must take place to build a conceptual model. First, the problem should be identified and demarcated. Second, the problem situation should be translated into a conceptual model. The problem owner and decision maker provide the analyst with information, mostly in the form of oral or written text, to carry out these activities. The analyst usually reports back with a conceptual model.

B. The analyst collects data to quantify the elements and relationships between these elements in the conceptual model. The problem owner provides this data, mostly in the form of text. The analyst then builds the simulation model. Graphical interfaces for building simulations have been developed. These visual tools are expressive enough to be used to assemble complete simulation models and to specify alternative simulation runs (Ozden 1991). Most of these tools, however, still require the user to have simulation expertise (Kuljis et al. 2001).

   Before the model can be used, it must be verified and validated. Animations can be used as a verification aid for creating models. Animation models may decrease the development time of the simulation model, because of the enhanced debugging possibilities. With animation it might be quicker to find and localize mistakes than by going through output of traces or using a debugger (Vreede and Verbraeck 1996). However, a correctly functioning animation does not imply a completely debugged model, much less a verified model (Johnson and Poorte 1988).

   Animations can be helpful in the validation of the simulation models as well. Because of the 'cartoonlike' behavior, animations have the potential to resemble closely the mental models of the problem owners involved. Hence, it is easier to communicate to problem owners. As a result, animations offer unique possibilities for face-validity tests. Structural mistakes in the model or deviant model behavior can be pointed out by problem owners. Animations, however, can only be used to show that a simulation model is not valid (Law and Kelton 1991). Furthermore, animations do not support the 'statistical' validation that is required besides the face-validity.

   If the model is verified and validated, it can be used to identify causes and effects of the problem.

Animations can enhance the problem diagnosis. Animations provide more insight into deadlock situations, system bottlenecks, queue lengths, and so on. Furthermore, an animation can illustrate the statistical results of a process analysis in an accessible way. There is no need for decision makers to go through large amounts of numerical data afterwards (Vreede and Verbraeck 1996). Animations can even be considered a better way to illustrate results to decision makers: seeing it is believing it (McHaney 1991). Some reserve, however, must be taken into consideration, since snapshots of a running visual simulation are a dangerous yardstick to determine what is going on in the system over time (Grant and Weiner 1986, Paul 1991). The statistical output after running several replications with the model should be used as well to come to firmly grounded and statistically sound conclusions.

C. Based upon the results from the problem diagnosis, several alternative solutions may be generated. The problem owner and decision maker discuss these solutions with the analyst. The analyst translates these into alternative simulation models. The changes to the simulation model can take place at two levels: changing the structure (the elements and the relationships between these elements) and changing the data (the parameters in the model). The analyst can use a graphical interface to make those changes.
   Once the alternative models are finished, they should be run to analyze the results. The same visualization means can be used as with the problem diagnosis. An extra dimension, however, can be added for conducting experiments. In diagnosing the problem, one situation must be analyzed, but in conducting experiments, different situations should be compared with each other. An animation allows to show the results of one situation only. The statistical output of the different alternatives should be presented next to each other to enable comparison between the alternatives.
D. The results of the simulation study are reported about. This usually is a document prepared by the analyst and used by the problem owner and the decision maker. The decision maker decides based on the results reported.
E. Finally, the solution chosen is implemented. This step is often outside the scope of the simulation study.

Concluding from this, it can be stated that visualization is used in many different ways to enhance the communication between the analyst and the problem owner and the decision maker. It is also noted that, despite the enhanced communication, the analyst still functions as an interface between the model and the decision maker and the problem owner. To enable non-modeling experts to really work with simulation models in all steps of a simulation study requires more advanced visualization means than currently used. We distinguish three visualization modules: a visual input module, a visual run module, and a visual output module. The visual input module should enable the non-modeling expert to enter information on the structure and data of the problem situation to build the simulation model. Graphical interfaces to enter this information already exist. Interfaces to enter information on the structure, however, often require simulation expertise. Interfaces to enter the data, on the other hand, are open to non-modeling experts, especially when the choices are prestructured. The visual run module already exists in the form of animations. As already noted, animations make the simulation model more accessible to non-

Step	**Visualization means**	**Visualization topic**	**From**	**To**
(1) (2) problem demarcation	text text	different aspects of the problem	po/dm an	an po/dm
(3) model conceptualization	text conceptual model	elements and relationships between the elements	po an	an po
(4) data collection	text	numerical data on the elements and relationships	po	an
(5) model translation	simulation code graphical interface	structure + data	an	
(6) verification	animation	structure + data	an	
(7) validation	animation	structure + data	an	po
problem diagnosis	animation	structure + data	an	po/dm
(8) experimental design	text graphical interface	structure + data	po/dm an	an
(9) runs and analysis	animation statistical output	structure + data + output	an	po/dm
(11) report	text	structure + data + output	an	po/dm
(12) implementation	-	-	-	-

po = problem owner; dm = decision maker; an = analyst

Table 1: Visualization to enhance communication in simulation studies

modeling experts, but they present snapshots only. To get a complete picture of the problem situation modeled, the visual output module is required. The visual output module presents the statistically sound results of the simulation model after several replications. Although each of the three modules already exists in some way, it is not clear whether they are sufficient to enable the non-modeling expert to work with the simulation model without the support of the analyst. Bell et al. (1990) state that great challenges exist to build visual simulation tools to support decision makers. In the next section we take up this challenge in a case study. In the case study we developed a simulation model to be used by non-modeling experts without the support of analysts.

3. THE RCCT STUDY APPROACH

The Regional Collecting Controlling and Tracing (RCCT) department of the Amsterdam Municipal Police Force processes the charges of civilians, for example for speeding, ignoring red light, and parking wrongly. About 5600 police officers, divided over eight different districts in the region of Amsterdam, observe violations of rules by civilians. These violations are summarized in a charge. These charges have to be processed in order to be sure that the civilian pays the fine. The managers of the RCCT are in search for support in deciding how these processes should be carried out. Several reasons for this can be indicated.

- First and most important, the Amsterdam Municipal Police Force wants to cut down the processing times for the charges.
- Second, the managers want a tool to analyze the possibilities of different ICT applications to speed up the process. Personal handhelds, for example, could be used by the police offers to summarize the violations. This would replace the written charges and could result in less errors due to unreadable charges and incomplete charges. Another ICT application could be the automatic recognition of license plates on photographs taken of cars violating traffic rules.
- Third, the RCCT must deal with a dynamic environment, requiring the RCCT to adapt their processes to the changes in the environment. One of the most important influences is the amount of charges entering the RCCT. The amount of charges that have to be processed is very fluctuating. Some examples are described to show this fluctuation. A first example is that the number of charges increases at the end of the month, because police officers have to meet targets on the number of charges they have issued. Another example is the formulation of projects by the Amsterdam Municipal Police Force to attract special attention of civilians to certain areas. Speeding, for example, might be a special topic for a month, resulting in more charges on speeding that month. These fluctuations have an unpredictable nature. Another example is the reorganization of processes: the issuing of charges for parking at the wrong spots was delegated to parking officers, but will be added to the tasks of police officers. This means an increase of charges for the RCCT.

To deal with the situations mentioned above, the RCCT managers need an automated tool for designing the processes to meet the expected flow of charges. This tool must be able to simulate the flows through the organization over time. The tool must have a good representation of the processes within the organization to be able to predict the performance. Ultimately, the tool must allow the managers to define 'what if' scenarios. Two major goals for the system are to provide a visual development environment and to display the results in an easy to understand visualization.

In the case study, a dynamic model has been built in Arena®, a dynamic modeling language allowing for the combination of simulation and animation. A conceptual model has been build by analyzing the processes and interviewing employees. The data for the simulation model was collected by using existing databases and by measuring several indicators of the processes, such as processing times. With the conceptual model and the data, the simulation model was built. The model was verified and validated and after some slight modifications a good simulation model resulted.

The simulation model was combined with visualization through the three different modules. First, an animation of the simulation model has been built. The animation shows the flow of the charges through the organization, shows the number of employees working on the charges and shows the different queues of the charges. Figure 2 shows a screendump of the animation. The animation shows the seven different divisions within RCCT as well as the work load for each division.

Second, a visual input module for changing the simulation model has been developed. The visual input module does not offer possibilities to change the structure of the simulation model; only the data used in the simulation model can be changed. The visual input module has been realized using VBA (Visual Basic for Applications) and is connected dynamically to the simulation model. This means that even during a simulation run changes to the model can be made, instead of only after a simulation run. Interaction with the simulation model is possible. An interface has been designed in which the managers can change the number of employees working at each process, the processing times, the number of charges entering the RCCT, and so on. Figure 3 shows a screendump of the visual input module. The visual input module contains several of these sheets to change all data relevant.

And third, a visual output module for presenting the statistical output of the simulation model has been built. Relevant information to managers on, for example, throughput times, queue lengths, and occupation of employees are presented graphically over time so an analysis of the performance of the system can be made

Figure 2: Animation of the RCCT

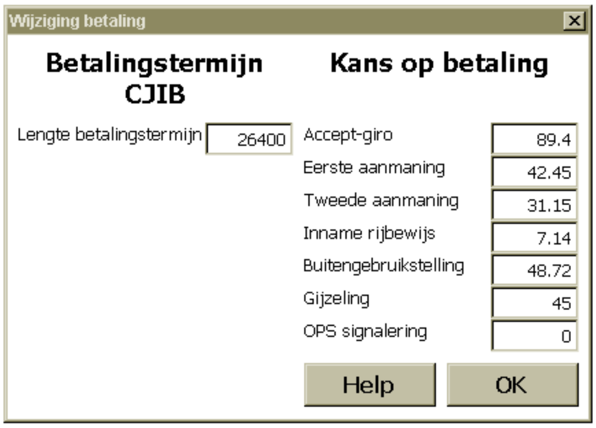

Figure 3: Visual Change Module of the RCCT-Case

by the decision makers.

The visual output module has been realized in Microsoft® Excel. The visual output module only reads in the results of a simulation run after the run has finished. The status of the system during the simulation run is visible through the animation, but a thorough analysis of the results is possible through the visual output module. Figure 4 shows a screendump of the visual output module.

In order to evaluate whether the visualization elements indeed allow non-modeling experts to use simulation models in their decision making, the simulation model and visualization modules were presented to the managers of the RCCT. After the presentation, a questionnaire was filled in by the managers to get a

OK Resultaten ROE

Doorlooptijd (in uren)	Gemiddelde	Halfwaarde	Minimale waarde	Maximale waarde
M121	20,89	0,31	5,01	42,43
Sloop & bewaar	4,17	#######	0,24	12,17
Wet Terwee	0,62	#######	0,20	4,18
Parate executie met	5,84	0,68	0,20	19,94
Parate executie zonc	6,31	#######	0,51	25,02
Beschikking	6,85	0,86	0,28	29,92
Politie transactie	5,33	0,75	0,17	24,99
Waarschuwing rijbew	10,47	0,21	3,76	17,54
Waarschuwing gebrui	16,75	0,17	10,60	22,69
Waarschuwing gijzeli	15,05	0,16	10,60	20,63
OPS Signalering	13,85	0,16	10,61	18,93

Aantal in wachtrij	Gemiddelde	Minimale waarde	Maximale waarde
M121	39,95	0,00	110,00
Informeren LCA	4,33	0,00	34,00
Sloop & bewaar	0,06	0,00	3,00
Wet Terwee	0,00	0,00	0,00
Parate executie met	0,74	0,00	9,00
Parate executie zonc	0,08	0,00	4,00
Beschikking	1,24	0,00	16,00
Politie transactie	1,30	0,00	20,00
Waarschuwing rijbew	58,99	0,00	254,00
Waarschuwing gebrui	62,58	0,00	301,00
Waarschuwing gijzeli	21,80	0,00	142,00
OPS Signalering	8,96	0,00	86,00

Gemiddelde werkdruk
0,76

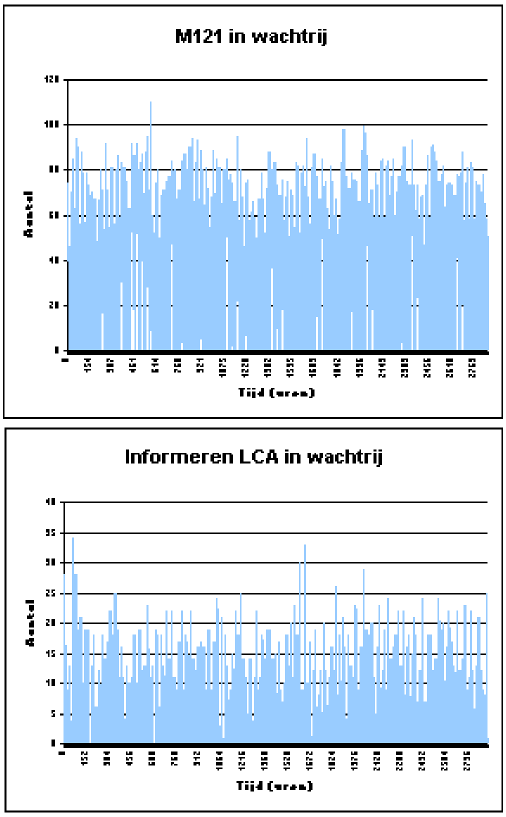

Figure 4: Visual Output Module of the RCCT-Case

feeling of the usefulness of the visualization elements. The questionnaire as well as the results are presented in the next section.

4. RESULTS OF THE RCCT STUDY

The visual modules were evaluated using a questionnaire. In the questionnaire, the managers could indicate how they evaluate the different modules on different criteria. Each module is discussed in a separate paragraph, starting with the animation. The design of the interface is generally considered to be good. One manager indicated that the design was bad. Compared to many computer games available today, the design indeed looks bad, with robotic people sitting behind a desk, but for the purpose of the animation, most managers agree about the design to be good. The arrangement and the clarity of the animation elements are considered to be good, as well as the completeness. Furthermore, the animation is considered to be user-friendly.

Table 2: Results on the Animation (n = 10, 1 is very bad, 5 is very good)

Criteria	**1**	**2**	**3**	**4**	**5**	**μ**	**σ**
Design	0	1	0	6	3	4,1	0,88
Clear arrangement	0	0	0	9	2	4,2	0,42
Clarity	0	0	0	8	1	4,1	0,32
Completeness	0	0	0	7	3	4,3	0,48
User-friendliness	0	0	1	7	2	4,1	0,57

The results for the visual input module are presented in the table below. Especially the design is considered to be very good. The elements are arranged in a clear manner and the clarity of the elements is considered to be good as well. With regard to completeness and user-friendliness, the overall opinion is that the visual input module is good. However, some managers are not yet really convinced of this, since they have a neutral opinion.

Table 3: Results on the Visual Input Module (n = 10, 1 is very bad, 5 is very good)

Criteria	**1**	**2**	**3**	**4**	**5**	**μ**	**σ**
Design	0	0	0	4	6	4,6	0,52
Clear arrangement	0	0	1	8	1	4,0	0,47
Clarity	0	0	0	6	2	4,0	0,67
Completeness	0	0	2	5	5	4,5	0,53
User-friendliness	0	0	3	6	1	3,8	0,63

Finally, the visual output module is evaluated, the results of which are presented in Table 4. The overall opinion is that the visual output module is good. However, the standard deviation is slightly higher than for the other modules. This is true especially for the clarity and the user-friendliness of the module. The enormous amount of statistical output will partly be due to this.

Table 4: Results on the Visual Output Module (n = 10, 1 is very bad, 5 is very good)

Criteria	**1**	**2**	**3**	**4**	**5**	**μ**	**Σ**
Design	0	0	2	3	5	4,3	0,82
Clear arrangement	0	0	1	4	5	4,4	0,70
Clarity	0	1	2	4	3	3,9	0,99
Completeness	0	0	0	6	4	4,4	0,52
User-friendliness	0	2	1	5	2	3,7	1,06

The questionnaire filled in by the managers was concluded with the overall question, whether they believed that the tool is usable in their daily practice. With no exception, they all agreed that the tool is usable in their decision making processes.

5. CONCLUSIONS AND FUTURE RESEARCH

The case study described in this paper showed that a simulation model can be used by non simulation experts by adding visual elements to the simulation model. Prior case studies in which a simulation model and visualization were combined, show that usually the analyst still fulfills the role of human interface between the model and the non-modeling expert. From this, it can be concluded that the visual input module and the visual output module have added value for decision makers. More case studies and experiments, however, should be carried out to give more depth to this conclusion.

The visual modules used in the case study, however, only support decision makers in a part of the decision making process. Problem diagnosis, construction of alternatives, and experimentation are activities that are supported by the visualization. The construction of alternatives is only partly supported, since the decision maker can only change the data of the simulation model and not the structure of the simulation model. Furthermore, the activities concerned with building, verifying and validating the simulation model are not supported well enough yet by visual elements to allow the non-modeling experts to work without the support of the analyst. These activities still must be carried out by a simulation specialist. Further research should focus on ways to expand the visual support to other activities as well.

During the construction of the simulation model and the visual modules, a trade-off existed between the flexibility and power of the simulation model, and the user-friendliness of the visual modules for non-modeling experts. One of the reasons for this trade-off is that most simulation languages are focused on offering the opportunity to build a simulation model. What simulation languages should focus on more and more is the opportunity to build a Decision Support System based on a simulation model.

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