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Igor S. Mayer, Wieke Bockstael-Blok and Edwin C. Valentin

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A building block approach to simulation: An evaluation using CONTAINERS ADRIFT

Igor S. Mayer
Wieke Bockstael-Blok
Edwin C. Valentin
Delft University of Technology

A building block approach to simulation uses modules that are easily reusable and therefore speed up the simulation process. The authors assume that this approach can enhance complex decision making between stakeholders on infrastructure planning and design. The authors combined insights from process management and a simulation building block approach into an experimental interactive decision-making procedure and developed a simulation building block tool. The authors tested the procedure and the tool in the game CONTAINERS ADRIFT. Evaluation results indicate that the simulation tool is fast and easy to work with and that the combination of simulation building blocks and process management contributes to the quality and process of negotiation and generates mutual understanding.

KEYWORDS: *computer-based simulation; container terminal; decision support system; dynamic modeling; gaming; infrastructure management; planning; process management; simulation; simulation building blocks; transportation; visualization*

The planning and design of infrastructures, such as airports, harbors, wind farms, and terminals, is a complex task because of a large number of interrelated design parameters and mutually dependent public and private stakeholders with different perceptions, interests, values, and objectives (Bockstael-Blok, 2001; De Bruijn & ten Heuvelhof, 2000; Mayer & Veeneman, 2002; Weijnen & ten Heuvelhof, 1999; Weijnen et al., 2000). As a consequence, the optimization of technical, economic, and logistic values, for instance by discrete event simulation, will be strongly inhibited by conflicting interests, political and external boundaries, and strategic stakeholder behavior. The design and planning of such infrastructures therefore requires careful management of the technological, economic, and logistic aspects, as well as the political aspects of the problem (Chisholm, 1989; Freeman, 1984; Kickert, Klijn, & Koppenjan, 1997).

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An interactive planning and design process involving experts and stakeholders that is supported with simulation tools can be powerful in such complex situations (Edelenbos, 1999; Eden & Ackermann, 1998; Vennix, 1996). Simulation tools that are used in interactive settings should, however, be valid, fast, and easy to use, and most of all should have the power to mediate and contribute to mutual understanding.

In this article, we present and evaluate if and how a simulation building block approach can be used for interactive planning and design of infrastructures in an environment that is both politically and technologically complex. For experimentation and teaching objectives, we developed a simulation building block tool and the game CONTAINERS ADRIFT. We used the planning and design of a fictitious but realistic inland container terminal as a case. In the next section, we will present the theoretical background of the study. We will then discuss the research approach, the outline of the game, and the findings. We finish with some observations and conclusions about the simulation building block approach.

Infrastructure planning and design

A process-oriented approach

From a decision-making perspective, the planning and design of infrastructures can be characterized on the following two dimensions: (a) the degree of consensus on norms and values and (b) the degree of consensus on facts and causal relations (Hisschemöller & Hoppe, 1996). Most commonly, the planning and design of complex infrastructures will score low on both dimensions (i.e., a strong disagreement between stakeholders on values and norms in combination with a great many technological, economic, and logistical uncertainties). These situations are usually characterized as "ill-structured," "wicked," or "messy problems" (Mason & Mitroff, 1981).

The decision-making process under such conditions is known to have a number of characteristics, among others (De Bruijn & ten Heuvelhof, 2000; De Bruijn, ten Heuvelhof, & In't Veld, 2002):

- The planning and design process will be pluricentric in the sense that no single stakeholder can dominate or monopolize the decision making.
- It will be dynamic in the sense that the perceptions of problems and solutions will change over time. Stakeholders will enter and exit the decision-making arena and the process will progress by fits and starts.
- Stakeholders will behave strategically to optimize their own interests and values.

Whereas stringent project management may become crucial in later stages of infrastructure planning and design, the management of relations between stakeholders and the stakeholder negotiation process itself are essential during the initial stages of the project (De Bruijn et al., 2002). To avoid impasses and breach stalemates, the interorganizational decision-making process (i.e., who is going to decide about what, how, when, and under what conditions) must be carefully designed and managed.

In recent publications, process management—a theory of meta-decision making—has been presented as a useful approach to manage such complex situations (De Bruijn et al., 2002). In short, the process management approach is based on the following four meta-decision-making principles:

1. The decision-making process should be open for (participation by) the key stakeholders and the different perspectives on problems and solutions.
2. The core values of these stakeholders, such as autonomy or commercial property rights, should be safeguarded and respected.
3. The decision-making process should show progress and produce timely results.
4. The level of understanding and knowledge of the various stakeholders on the subject at hand should be raised by feeding information and analysis into the negotiation process (De Bruijn et al., 2002).

In other words, during the early stages of planning and design of infrastructures, an intricate balance is required between the following:

- The content of decision making, for example by providing the relevant factual information and assessments through analysis.
- The interorganizational decision-making process that can be characterized as participatory and safe, that shows progression, and that integrates different sources of knowledge.

In particular, at an early stage, an independent process manager may design and facilitate the decision-making process, among others, by:

- Drawing up, in consultation with the stakeholders, a program with the various steps and rounds of decision making.
- Drawing up, in consultation with the stakeholders, a number of ground rules (e.g., on conflict settlement or exiting the process) that will guide and control the interaction between the participants.
- Facilitating the process through constantly shifting from content to process and vice versa.

The theory of process management, for instance, suggests that issues that are controversial should be put on a common agenda via process rules that express when and how the stakeholders are going to address these issues. When controversial issues are negotiated too early in the process, this may easily lead to an impasse. It may turn out that when the issue is discussed later in the process, stakeholders have become more sensitive to the positions of other stakeholders, so that the process provided interesting opportunities to make trade-offs or even that the issue is no longer relevant. Such principles of process design and ground rules of negotiation agreed on by the stakeholders have to be designed and maintained continuously by the process manager (Bockstael-Blok, 2001).

However, without feeding analysis and expert knowledge into the process, the risk is that participants will not learn or will even end up with negotiated nonsense. In this respect, an important question for the theory of process management is how, when, and to what purpose simulation tools can be used to support complex decision-making processes. The reverse question is equally relevant: How can insights from process management enhance interactive simulation processes and thus the effectiveness of simulation tools? As we will argue, one possible solution is the combination of process management and a simulation building block approach. We will first describe the simulation building block approach and then show how it can be combined with process management.

A simulation building block approach

A discrete-event simulation is one in which the state of a model changes at only a discrete, but possibly random, set of simulated time points (Schriber & Brunner, 2002, 98). Discrete event simulation is a powerful methodology for evaluating the (logistical) design of infrastructure systems, such as airports, harbors, and railways, still to be built (Banks, 1998). However, several authors have concluded that the level of knowledge and the amount of time required to build, adjust, and run such a simulation model constitutes a major obstacle for interactive stakeholder decision making (Keller, Harrell, & Leavy, 1991; Law & McComas, 1989; Robinson, 1999; Sadowski & Grabau, 2000).

From a process management point of view (see above), this is a serious handicap because when discrete event simulations are used, the interactive decision-making process runs the risk of losing momentum. Stakeholders such as residents and environmental associations are likely to drop out. Specific requirements for the use of simulation tools in interorganizational networks would therefore include the following:

- They are valid.
- They are transparent.
- They are fast and easy to work with.
- They can cope with information relevant to various stakeholders.
- They support the negotiation process by generating mutual understanding about the issue.

Hooghiemstra and Teunisse (1998) presented an interesting solution to the aforementioned obstacles for using discrete event simulation in interactive stakeholder decision making. Their solution is based on using simulation building blocks. In a case on railway planning, they developed a simulation tool based on a database with information on the railway network and the train timetables. This tool allows even nonexpert users to construct and evaluate simulations models almost automatically. This approach has been developed further in projects for automatic guided vehicles (Verbraeck, Saanen, & Valentin, 1998) and passenger handling at airports (Verbraeck & Valentin, 2002).

In another study on a building block approach, Maghnouji, Vreede, Verbraeck, and Sol (2001) concluded that visualization is also an important element for stakeholder decision making, for instance by using visualization and animation techniques in interactive stakeholder sessions. Visualizations of a system, such as sketches and layouts, place a design in its future environment, communicate the complexity of the system, and show the consequences of options. Simulation and animation models are, in addition, able to express a system's dynamic characteristics.

The above examples of using building blocks for simulation and visualization inspired us to explore further the potentials of using a simulation building block approach for interactive modeling of infrastructure systems in a complex political and technical environment. Simulation tools based on building blocks support the making of simulation models that have high face validity, making the models suitable for effective and efficient communication between simulation experts, decision makers, and stakeholders (see Valentin & Verbraeck, 2002; Verbraeck & Valentin, 2002). Below, we will first outline the simulation building block approach and then discuss how it can be combined with process management.

A simulation building block approach is a general way of thinking, modeling, and working that is based on object-oriented concepts and reusability of small model parts (Valentin & Verbraeck, 2002). The approach relies on a tailor-made but flexible simulation tool in which Visual Building Blocks play a key role. Visual Building Blocks are based on Mental Building Blocks that are defined during the development of the tool. Mental Building Blocks are specific sets of components representing what the stakeholders may encounter in their system design (e.g., a road, a truck, or a container storage). The Visual Building Blocks are the visual representations of the Mental Building Blocks. Users of the simulation tool (e.g., stakeholders and experts) can construct a visualization of the system's design by selecting and connecting the various Visual Building Blocks. Such a visualization, for instance of a container terminal, does not yet give any indications about the performance of the design. The simulation tool therefore supports the transfer of the Visual Building Blocks into Simulation Building Blocks by attaching functionalities and parameters to the Visual Building Blocks. Subsequently, the visual representation of the design can automatically be loaded into dynamic simulation packages such as ARENA (www.arenasimulation. com) and PROMODEL (www.promodel.com). System performance data are collected from the simulation statistics of the Simulation Building Blocks and can be pasted into a status report tailor-made for the problem at hand.

Coupling of process and simulation

In our view, the process management approach and the simulation building block approach, as described in the previous section, can be highly complementary. The simulation building block approach provides the required feedback of information and analysis into an interorganizational decision-making process. Process management, on the other hand, provides guidelines and rules for an interactive simulation setting involving multiple stakeholders. Interactive simulation contributes to openness among stakeholders for different perspectives and alternative solutions. At the same time, the simulation of alternative designs constitutes a reality check. It also forces stakeholders to be explicit about their design choices and challenges their assumptions on causes and effects.

The coupling of process management and simulation for infrastructure design can lead to a cyclical decision-making and design process connecting a long cycle of process design and a short cycle of simulation to support infrastructure planning and design, in the following way (see also Figure 1):

1. Process managers draw up in consultation with stakeholders a program and a set of ground rules for the interactive decision-making process.
2. Interacting groups of stakeholders draw visualizations or sketches of possible infrastructure designs with the simulation tool.
3. Interacting groups of stakeholders negotiate on the important parameters for the design and enter this data in the simulation tool.
4. Interacting groups of stakeholders build and run the simulation model. In fact, the simulation tool performs these tasks for the stakeholder groups at the push of a button.
5. Stakeholders assess the performance of the design. The stakeholders can decide to go through the small cycle again from Step 2 onwards, or go to the next stage.
6. The next stage is one in which they identify the major decision points and controversies in the discussion. These issues can then be put on the common decision agenda. The stakeholders should then suggest procedural steps and rules for subsequent negotiation on these issues (going back to Step 1). If deemed necessary, stakeholders can go through the cycle again from Step 2, now focusing on specific details or controversies in the negotiation.

The building block approach and the proposed way of working with a simulation building block tool (see above) are general, but the selection and specification of the building blocks are depended on the (real or fictitious) case at hand. To develop a simulation building block tool and try it out in connection with process management, we needed a realistic case and a relatively safe and repeatable experimental environment.

Research approach

Development of the game and the simulation tool

To test and validate the aforementioned combination of process management and simulation building blocks, we developed a case-specific simulation tool and a game. We opted for the design of an inland container terminal as a case. A quick scan indicated that the issue of container terminal planning is high on the political agenda in the Netherlands and that it has sufficient complexity in terms of interdependent stakeholders and interrelated parameters. The characteristics of the important elements for a terminal design such as its location, the quays, roads, ships, trucks, cranes, and containers gave adequate opportunity to develop a sophisticated but usable simulation tool.

Faced with the challenge of increasing the speed and ease of the design cycle, we developed a simulation tool that allows the stakeholders to go through the long cycle in about a day and several short cycles in a few hours (see Figure 1). To be able to experiment and repeat the procedure, the tool was embedded into the game CONTAINERS ADRIFT. In this game, the participants play the role of stakeholders and explore and

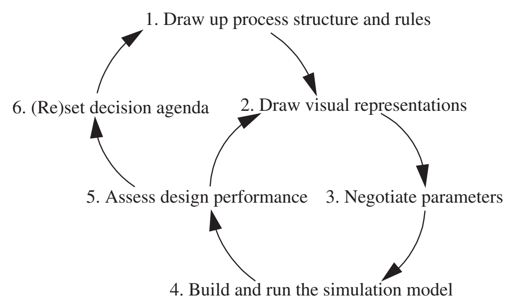

FIGURE 1: The Cyclical Decision-Making and Design Process

negotiate on a container terminal design while using our simulation tool. In the remaining part of this section, we will discuss the game design, the tool design, the evaluation approach, and our expectations about the tool and the process.

Game design

The game design process largely followed the design steps as described by Duke (1980, see also Crookall & Arai, 1995; Duke, 2000; Geurts, Joldersma, & Roelofs, 1998; Greenblatt, 1988). We conducted a systems analysis of an inland container terminal including document studies, interviews, and visits to existing container terminals. We gathered technical, economic, financial, and geographical data on container terminals and used these for the game scenario, maps, and the simulation tool.

Tool design

The simulation tool is used to design and evaluate designs of a container terminal. The simulation tool was customized for the game. The tool is available for all roles on four to six modeling stations with fast computers and projectors. The simulation tool consists of the following four parts:

1. A drawing tool for the general layout of the terminal.
2. A database containing information on essential building blocks.
3. A discrete event simulation tool for the evaluation of a terminal design on logistic parameters.
4. A spreadsheet for the presentation of performance indicators.

An earlier review of about 50 simulation environments led to the conclusion that no simulation environment exists that combines all these four parts (Tewoldeberhan, 2001). We therefore used different tools for each part: Visio, MS Access, ARENA, and MS Excel, respectively. The four different tools are connected with Visual Basic for Applications.

The computational model, at the heart of the simulation tool, is based on interrelated logistic and operational processes that determine the terminal's performance. To give an example: without enough trucks to transport the containers to a company, too many containers will stay in storage. New containers cannot be moved out of a ship and therefore new ships cannot arrive. The lead time of river transport will increase considerably.

The exact relationship between decisions and effects is hard to predict because of the dynamic character of the interaction. Discrete event simulation (Law & Kelton, 1999) is used to gain insight into a terminal design's performance. Under normal conditions, the development of a discrete event simulation model will take too long for a game. Depending on the level of detail, it may take several weeks (Banks, 1998).

The simulation building block approach used for the game should allow the stakeholders to develop a discrete event simulation model in about 15 minutes. The simulation tool for CONTAINERS ADRIFT uses 15 different simulation building blocks, exactly matching the visual building blocks, implemented in the simulation environment ARENA (www.arenasimulations.com). Several control mechanisms organize the simulation process so that a simulation model is generated and executed more or less automatically.

Over time, the simulation tool and game have been refined and extended but have not been changed markedly. In the following sections, the tool and the game CONTAINERS ADRIFT are described in more detail. First, the evaluation approach and our expectations of results are discussed.

Evaluation approach

During the past 2 years we held about 15 sessions of CONTAINERS ADRIFT. Sessions ranged from 2-hour demo versions to a 1½-month version. Besides for experimentation and testing, we used the game as a teaching environment, integrated into the master's curriculum of the faculty of Technology, Policy and Management of the Delft University of Technology. Most of the participants were master's students of systems engineering, policy analysis, and management. Some short sessions have been held with academic professionals. Although sessions with students may raise questions of reliability and validity, it is important to note that the objective of the experiment was to develop and test the tool and working procedure (see expectations below) before using it in real cases with real stakeholders.

Most participants were fairly experienced in using computer software such as Excel and ARENA (simulation software) but had much less experience in drawing with Visio, the drawing package used in the visualization tool. They usually also followed theoretical courses in management and decision making, but had little or no practical experience in process management and facilitation. In addition, they had little or no practical experience with using simulation tools for the support of complex decision making.

We evaluated all gaming-simulation sessions extensively. Empirical data were gathered through the following:

1. Observation during the game.
2. Plenary debriefing after each session.
3. A questionnaire about the tool filled out by the participants shortly after the game.
4. Written evaluation assignments.

We told the participants that the experiences and results of the sessions were going to be used for further improvement of the game and tools. The students' positive or negative opinions about the game and/or tool did not determine their grade. The response rates were near to 100%. The evaluation focuses on the following two main aspects:

- The role of the simulation tool in an interorganizational decision-making process.
- The functionalities and performance of the tool.

In the general discussion of our experiences with the tool and game, we draw on all 15 sessions. More detailed observations and statistics are presented from the most recent sessions only. These were two parallel gaming sessions with about 35 students in each session (i.e., a total number of about 70 participants). These sessions took place at the beginning of 2003 in a series of five game meetings over a period of about 1½ months. Each meeting lasted about 3 hours.

Expectations

The simulation tool was tested prior to the first game sessions. It showed stable performance. In a single-user version, it allowed us to go through the whole process of drawing, running, and evaluating a simple container terminal design in about 5 minutes. We assumed that during the game, interacting groups of stakeholders would be able to make and run a simple design in 15 minutes.

We furthermore expected that the tool would speed up the whole decision-making process. The tool would enable the participants to go through the long simulation cycle in 1 day and several small cycles in a few hours. The main question was whether the participants would be able to structure these design cycles themselves and if so, what this structure would be. What rules of interaction would they formulate to facilitate this process?

We also assumed that the use of the tool would enhance mutual understanding among stakeholders about their different interests and perceptions. This should contribute to the development of mutual trust. We further expected that the process structure and agreements in combination with the simulation tool would lead to a number of tentative but high-quality terminal designs. The evaluation of these alternative designs would lead to new insights about the important decisions and possible impacts of a container terminal. These decisions and impacts can then be put on a common decision agenda.

The use of a simulation tool in interorganizational decision making can also have reverse effects. Possible disturbing effects on the quality of the decision-making process are (a) the model may overdominate the negotiation process (i.e., important issues that cannot be simulated are pushed off the agenda), (b) the prefixed drawing and

FIGURE 2: Stakeholder Groups Designing a Container Terminal

building blocks in the tool may limit creativity and inhibit (radical) innovations in the design, and (c) actors may use the tool strategically (i.e., they may withhold or manipulate crucial information).

In summary, our expectations with respect to the simulation tool in the game were as follows:

- The tool enables building and evaluating a terminal design in about 15 minutes and speeds up the whole decision-making process.
- The tool supports the development of mutual understanding.
- The tool leads to tentative but high-quality terminal designs.
- Possible negative effects of the tool are overdominance of the tool, limitation of creativity, and strategic use of the tool.

The game CONTAINERS ADRIFT

Objectives

The game CONTAINERS ADRIFT focuses on the early stage of decision making about an inland container terminal to be located near the fictitious provincial town of Maaswijk. The objectives of CONTAINERS ADRIFT as a training environment were defined as follows:

- To provide a complex technical system design environment in which participants—either students or real stakeholders—can experiment with a process-oriented management approach to an interactive planning and design process.
- To provide a safe but complex social-political environment in which participants can learn and experiment with interactive simulation tools based on building blocks.
- To learn and reflect on the combination and integration of insights and techniques from process management and systems design, both for academic research and teaching and support of real-life design processes.

CONTAINERS ADRIFT can be played with 25 to 35 participants divided over 10 roles. The various stakeholders in the game are as follows: the Ministry of Transport, the container terminal operator Mega Container Terminal (MCT), the municipality of Maaswijk, the province of North Brabant, a commercial bank, potential customers of the terminal such as Holland Food, an association of local residents, a local environmental group, and various companies involved in shipping, logistics, and transportation. Two to four participants play each role as a team.

The game scenario

The game scenario, or plot of events, describes the background of the case, the characteristics of the municipality of Maaswijk, and gives an overview of the roles and the tasks and competencies of each role. In general terms, the plot of the scenario is as follows.

In recent years, a significant increase in the demand for transportation of goods has led to serious negative effects in terms of congestion and environmental damage. In its national freight policy, the Ministry of Transport therefore enhances the development of intermodal means of transportation. In the Netherlands, this implies making optimal use of innovative combinations of waterway, railway, and road transportation. Inland container terminals are an inevitable link in these intermodal transportation chains.

A policy scan has shown that it is worth exploring the feasibility of an inland container terminal situated in a neglected harbor area near a major waterway and industrial zone in the town of Maaswijk. MCT, a large German container terminal operator, has shown interest in developing the project commercially. However, many local and regional stakeholders are needed to realize the terminal. The terminal will have to be financed, it will have to meet customers' demands, the municipality and province will have to approve and cooperate, and local residents and environmentalists may obstruct and delay the project by starting legal procedures.

The Ministry of Transport and MCT have set up a joint project group. The process managers of this project group are made responsible for the initial negotiation and information process with all important stakeholders in the region.

The Ministry of Transport will only subsidize the container terminal if a number of social, financial, economic, and environmental criteria are met. At the end of the game, therefore, the participants are required to present the Director General of the Ministry of Transport with a (few) design(s) of a container terminal, indicating its financial, logistic, and environmental feasibility. The designs of the container terminal are the result of an interactive design process that takes place during the game using the simulation tool. The level of support for the container terminal and the continuation of the process have to be expressed by the stakeholders in a covenant. This covenant specifies the agreements on procedure and project and sets the agenda for further negotiation.

The steps of play

Before the game, the participants are briefed about its objectives and procedures. The simulation tool they will be using is demonstrated. The participants are given some time to read the manuals and role descriptions, prepare their role, and discuss their stakes and interest with fellow team members. During the game, the participants go through both the long cycle of process design and the short cycle of simulation in Figure 1.

The long cycle: process design and agenda setting. The process managers have the difficult task of drawing up a process design for the negotiations and planning of the terminal (see item 1 in Figure 1). The process managers are instructed in their role description that the general idea in this early stage of the project is to have an overall and interorganizational exploration of the political, social, environmental, economic, and logistic feasibility of the container terminal. The aim is to reach a preliminary agreement—a go/no-go decision—among all stakeholders for the next stage of design and decision making. The development of a shared vision of the container terminal and the identification of the items on the agenda are crucial at this stage. Not all disagreements or problems have to be settled. No decisions on the final design for the container terminal have to be made yet. The main objectives for the process managers are:

- that conflicting interests and disagreements are recognized and put on a common agenda;
- that the various conditions for stakeholder cooperation are met;
- that stakeholders speak a common language and understand the basic implications for the design of a terminal; but, most of all,
- that the necessary level of trust between stakeholders is achieved.

In consultation with all actors, the process managers have to come up with a structure—or program—as well as some ground rules for the interactive design process of the terminal. Important questions for the process managers at this stage are as follows:

- Are all stakeholders actually going to use the simulation tool or will only a few stakeholders use the tool, whereas others negotiate on other aspects without using it?
- Are the design teams going to be heterogeneous (i.e., mixing all sorts of interests and stakeholders in a joint design session) or homogeneous (i.e., private companies in one team, residents and environmentalists in another team, etc.)?
- How will small group sessions alternate with plenary sessions?
- How are the alternative designs of various design teams going to be compared?
- What ground rules between the players can be established to ensure that the four meta-decision-making principles concerning openness, core values, progress, and substantive knowledge are respected (see above)?

In other words, the stakeholders in the game first have to agree on how they are going to design and use the simulation tools rather than just start using the tool without careful deliberation.

After initial consultation with all stakeholders, the process managers present a draft process design. In a plenary session, the stakeholders may react and comment on this proposal and suggest adaptations. Only after the process design has been approved can the participants proceed with the visualization and simulation of the container terminal design, following the agreed process structure and ground rules (see Figure 1).

The process design for this second part of the game varies from session to session but is usually based on three to four parallel design meetings—with teams of about eight participants—alternating with plenary discussions and presentations of intermediate results. In parallel, a covenant with agreements for the next stage—which is not part of the game—is drafted. The designs and the covenant supported by the key stakeholders are presented to the Director General of the Ministry of Transport. The game is then brought to an end, more or less at the start of a new decision-making and design cycle (see Figure 1). The process and results are evaluated with the participants in a plenary discussion.

The short cycle: simulation for terminal design and evaluation. The decision of when and how to deploy the tool is left to the players in the process design phase. However, to design and evaluate a terminal with the tool the stakeholder groups are expected to go through the steps of the short cycle shown in Figure 1:

- Draw a visual representation.
- Negotiate parameters.
- Build and run simulation model.
- Assess design performance.

We discuss the use of the simulation tool in the game following these steps.

Draw a visual representation. The participants start the design process by sketching the terminal layout in the computer software program Visio 2000. The drawing tool contains a geographical map of the search area where the terminal has to be located. Visio provides the participants with the following set of visual building blocks for a container terminal: a quay, cranes, storages, roads, and parking lots for trucks.

Through negotiations, the stakeholders have to make trade-offs on the exact location of the terminal—in the north, middle, or south of the search area—and the different options for all drawing blocks such as the type and number of cranes and the length of the quay. Figure 3 gives an example of a container terminal drawing.

Negotiate parameters. The next stage of the design process is the selection of preferences in an Access database. The database contains quantified information about vehicles, trucks, ships, and customers. Through negotiations, the stakeholders have to decide on important options for the design such as the type and number of vehicles, trucks, and ships. Participants take into account their choices on cranes and the quay,

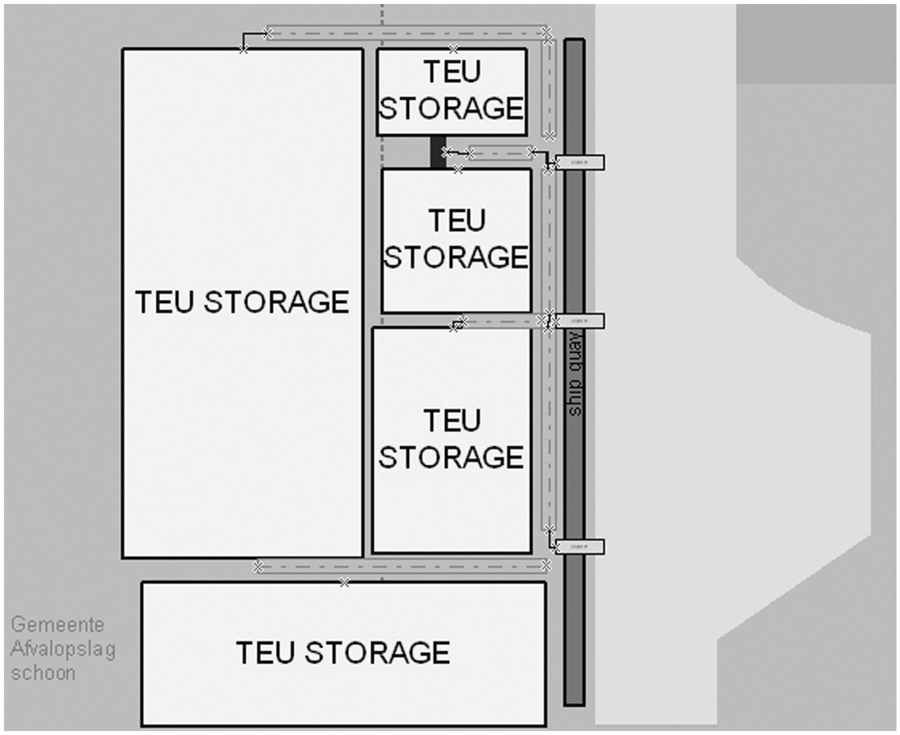

FIGURE 3: An Example of a Terminal Drawing

made previously in the Visio drawing. The participants have different preferences and need to make trade-offs—on their choice of ships, for example—taking into account that ships have different ship sizes and schedules. A ship schedule in combination with ship size, the number of cranes, and storage capacity influence the maximum number of customers the container terminal will be able to handle (see Figure 4).

Build and run the simulation model. After entering the parameters, the participants can simply select the menu option *run the model*. The tool automatically constructs an executable simulation model and runs it. The model simulates about 22 days of the terminal in operation and subsequently generates information on a variety of performance indicators.

Assess design performance. During the last stage of the visualization and simulation cycle, the outcomes of the simulation model are presented in a customized Excel sheet. The indicators are grouped in financial, logistic, and environmental indicators. The main financial indicators are costs, revenues, and required investments. The logistic indicators show the level of utilization of vehicles, parking lots, storage, trucks,

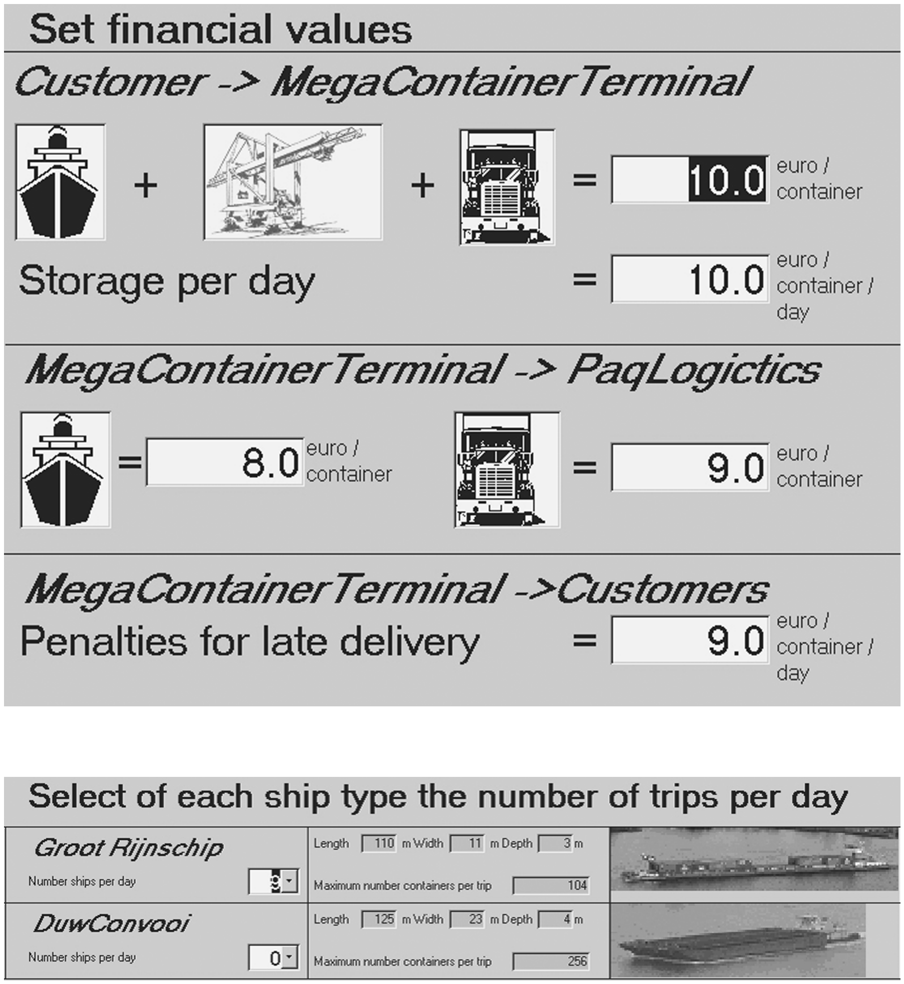

FIGURE 4: Examples of Entering Information About Customers, Ships, Vehicles, and Trucks Into the Database

ships, quays, and cranes. In addition, it shows queue lengths, waiting times, and lead times of various links in the intermodal chain of container movements.

Results and discussion

The most relevant findings regarding the use of the simulation tool in the interorganizational setting of the game are presented and discussed in this section.

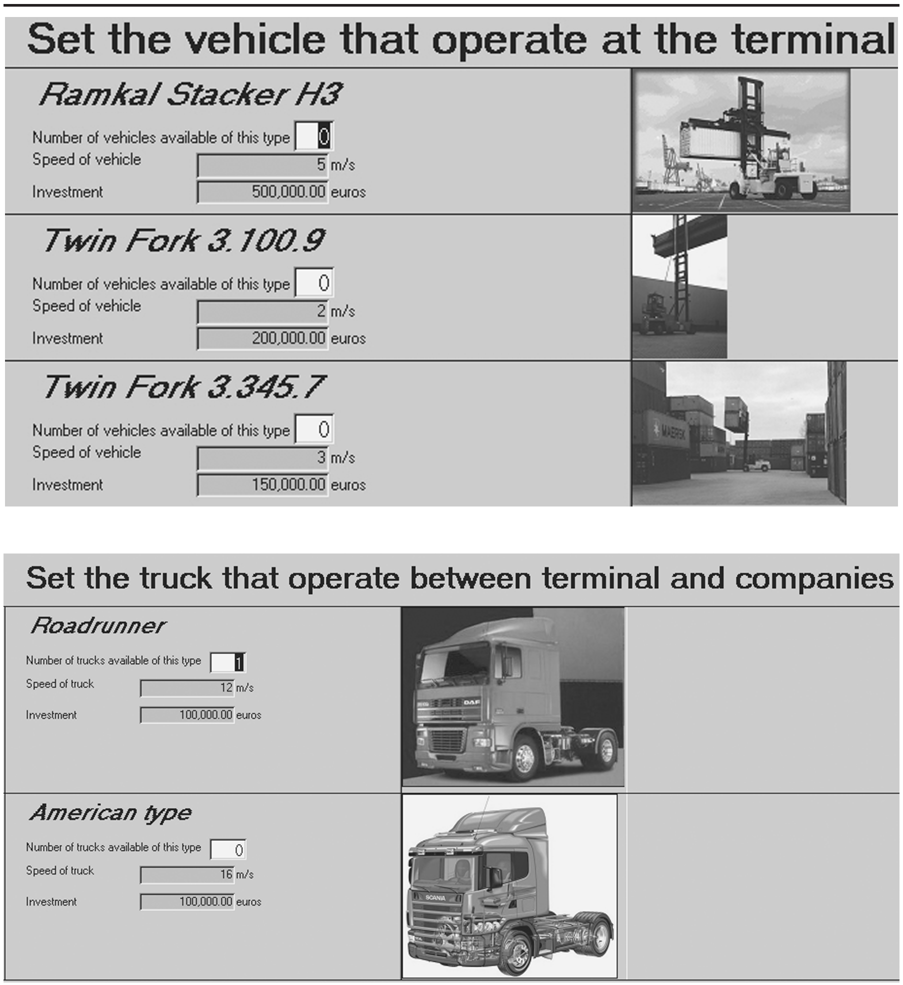

FIGURE 4: (continued)

First, we present a general discussion of the design and decision-making processes that evolved during the game, based on observations from the 15 game sessions held so far. After that, we present the findings of the evaluation. These are based on the most recent sessions only.

General discussion of the observed process

In the discussion of observations concerning the decision-making and design process and the use of the tool, we group the observations according to the following four major stages of the game:

- The first phase in which a process design is developed.
- Halfway, where the process design is consolidated. This appeared to be critical moment in most games.
- The second phase in which the participants work on terminal design using the simulation tool.
- The end of the game.

The first phase: developing a process design. We underestimated the difficulty the participants had in setting up and managing a process design. In nearly all sessions, the process managers needed a lot of time to reflect on how they were going to design and decide about the terminal. This may be because of the students' inexperience with process facilitation and management.

One of the unexpected pitfalls we observed was that, in many cases, the designated process managers adopted a very closed attitude toward the stakeholders. In some cases, they were very internally oriented and reluctant to arrange interaction with and among the stakeholders. During the debriefing, this was an important learning point for the participants.

Another pitfall we more or less expected was that both stakeholders and process managers immediately focused on the content and details of the terminal instead of focusing first on the decision-making process and putting the big issues on a common agenda. It appeared that it is very difficult for participants to realize that each stakeholder possesses a piece of the puzzle and that all sources of knowledge and preferences have to be brought into the planning and design process. The stakeholders tended to disconnect the issues into separate themes such as financing, logistics, environment, and location. They often did not realize immediately that these themes cannot easily be discussed or solved separately. Environmental issues, for instance, greatly depend on the chosen location and the number of ships, trucks, and so forth, that the terminal would service. This, of course, depends on the return on investments and logistical performance and so forth. Without simulated designs, the participants did not have a clue about the underlying dynamics, facts, and figures. The issues had to be considered in an integrated way, and the simulation tool allowed them to do just that.

In many sessions, powerful stakeholders were completely neglected by the process managers. As a result, some started to design their own container terminal, form coalitions, and put aside dissenting stakeholders. Disregarded stakeholders, of course, started complaining to the process managers and started looking for ways to block the decision making on the terminal. In a number of cases, environmentalists and citizens were on the verge of quitting the process and going to court.

Halfway: consolidating the process design. In many sessions, we were forced to push the process managers along. Halfway through the game, the process managers were usually ready to present a draft process design with some ground rules for interaction. Most important, ground rules that the stakeholders put forward concerned the sharing of sensitive (commercial) information, exiting the process, and not committing to the outcome of the process. Moreover, core values such as ecological concerns and formal decision-making authorities were identified and used as preconditions and starting points for the process.

Draft proposals of the process composed by the process managers often led to fierce debate and resistance by the stakeholders. During the interim plenary sessions, stakeholders raised many objections, for instance, on the compositions of the design teams, the type of designs they were going to make, and how these designs would be assessed.

At this stage, the process managers were usually struggling very hard to stay in charge. The plenary sessions about the process and the ground rules, however, greatly contributed to the understanding of the participants on what they were doing, how they wanted to design and plan the terminal, and how and to what benefit they could use the simulation tool. Gradually, and after heated discussions, a workable and effective process design was approved.

The process designs of the various gaming sessions differed markedly with regard to the grouping of stakeholders (e.g., homogenous groups or heterogeneous groups) and in the assignments given to the various subgroups (e.g., thematically based or scenario based). Moreover, various types of steering groups, working groups, and coordination procedures were set up. In most cases, ground rules and organization and coordination agreements were stipulated in a covenant accorded by all participants.

The second phase: terminal design with the simulation tool. During the second half of the game sessions, parallel subgroup meetings were usually organized according to the approved process design. At this point, the process managers normally regained their grip on the process. Because stakeholders now felt safer, they adopted a more constructive attitude. They were now ready to use the simulation tool for the exploration of the terminal. In parallel subgroups, the stakeholders discussed and negotiated on the location of the terminal, the length of the quay, the amount and type of cranes, the size and height of the container stacks, the location of the parking spots, the number of ships, the type of vehicles, and, finally, the customers and the financial values. Other points of discussion—such as the width of the ship sluice, noise levels, the ecological zone, and the yacht harbor—were also identified and put on the decision-making agenda. These qualitative issues cannot easily be simulated and therefore had to be explored in another way. In some cases, separate working groups were formed to explore and negotiate about these issues. Feedback of data from the simulation tool (e.g., the daily number of trucks and ships), however, remained relevant for settling these issues.

When highly controversial issues could not be solved immediately and were about to cause a deadlock, the process managers had to break the impasse by getting the stakeholders to stall the issue and reach an agreement on how and when they were going to settle them.

At this stage in the game, the participants really started to understand what a container terminal was, what consequences it had, what the prevailing choices and preferences were, how they could compromise and solve conflicts, and so forth. During the second part of the gaming sessions, all design teams were able to present one or more container terminal layouts with detailed assessments of its performance and consequences. The comparison of the container terminal designs was done in one or more (interim) plenary discussion(s) facilitated by the process managers.

The end of the game. Because of the pressure of time, the stakeholders were not always able to draft a full agreement or covenant at the end of the game. Instead, the process managers usually asked the participants to go back to their office and answer with their team one of the following questions: “Yes, we will support and cooperate in the next phase on the condition that . . .” or “No, we will not support and cooperate in the next phase because. . . .”

When all participants had presented their conditional yes or argued no, the designated process managers formulated their end conclusion to the group by presenting a general outline of the process that could follow. In nearly all sessions, the result was a conditional yes. Although stakeholders realized that a lot of issues still needed to be settled, the chaos and stalemates that characterized the first part of game had frequently disappeared. All games ended with interesting and in-depth debriefing discussions on process management and the role of the simulation tool. During the debriefing and evaluation, the participants indicated that they better understood the implications of the container terminal and that they had become more trustful about the proposal and the other stakeholders.

Evaluation findings

In general, the questionnaires confirmed many of our positive observations on the use of the tool and its combination with process management (see Table 1 for an overview). A large proportion (about 80%) of the participants in the various gaming sessions actively used the tool to make a terminal design. The remaining students engaged in other activities such as facilitation of the process and discussions of external (e.g., environmental) aspects of the terminal. The findings are discussed here in relation to the expectations we formulated earlier.

The tool enables building and evaluating a terminal design in about 15 minutes. It was expected that the tool would enable the design teams to make a general design of a container terminal in about 15 minutes. During the second part of the game, each design team would have time to go through several design cycles (see Figure 1), thereby enhancing learning. The respondents, however, estimated that the design cycle time had been between 60 minutes and 90 minutes. The following two factors slowed down the short design cycle considerably:

1. Actors, rightfully, needed much time to negotiate and make compromises, but. . . .
2. They were also reluctant to experiment with the tool by first going through a short design cycle, testing some assumptions, and seeing what happened. Most groups tried to optimize every stage and decision before going to the next stage. This usually did not contribute to the duration and the quality of the discussions.

TABLE 1: Assessment of Statements in Questionnaire

Statement	*Fully Disagree*	*Disagree*	*Neutral*	*Agree*	*Fully Agree*	M	SD
1. Making sketches with Visio has contributed to a better perception of the terminal	4.8	4.8	9.7	35.5	45.2	4.1	1.1
2. It was simple to build a (conceptual) model in Visio	4.9	4.9	31.1	27.9	31.1	3.8	1.1
3. The outcomes of the Excel model are easy to understand	3.2	11.3	22.6	33.9	29.0	3.7	1.1
4. The outcomes of the Excel model enhanced the discussion	4.8	11.3	19.4	35.5	29.0	3.7	1.1
5. The outcomes of the Excel model contributed to ideas for modification of the design	6.5	8.1	14.5	35.5	35.5	3.9	1.2
6. The simulation tool gave guidance during the discussion on alternative terminal designs	11.3	8.1	21.0	33.9	25.8	3.5	1.3
7. Without the simulation tool, we could not have made a design of the same quality and level of detail as we did during the gaming session	11.3	9.7	25.8	29.0	24.2	3.5	1.3
8. The simulation tool does not pay enough attention to long-term developments	3.2	14.5	35.5	25.8	21.0	3.5	1.1
9. The simulation tool does not pay enough attention to external developments	1.6	12.9	25.8	32.3	27.4	3.7	1.1
10. The simulation tool does not pay enough attention to environmental issues	4.8	11.3	32.3	25.8	25.8	3.6	1.1
11. The simulation tool positively enhanced the decision-making process	8.1	6.5	16.1	37.1	32.3	3.8	1.2
12. The simulation tool was fast enough for the gaming sessions	14.5	17.7	22.6	21.0	24.2	3.2	1.4
13. The simulation tool forces designers to take the interests and demands of other actors into account	14.5	8.1	30.6	30.6	16.1	3.3	1.3
14. The use of the simulation tool in interactive sessions contributed to mutual understanding	16.1	14.5	22.6	27.4	19.4	3.2	1.4

NOTE: Numbers represent valid percentage. Valid $N = 62$.

The tool leads to tentative but high-quality terminal designs. About 70% of the respondents (fully) agreed that the simulation tool positively enhanced the decision-making process. Without the tool, the participants would not have been able to reach the quality and level of detail as they did (21% disagreed). In particular, the drawing and sketching of the terminal in Visio was appreciated. The sketching was considered to be easy (10% disagreed) and valuable for getting a better perception of the terminal (80% of the respondents [fully] agreed). The performance of their drawings presented in Excel was also easy to understand (15% disagreed), stimulated the discussions (16% disagreed), and led to improvements of the design (15% disagreed).

The tool supports the development of mutual understanding. Less pronounced results concerned the development of mutual understanding. About 47% of the respondents indicated that the tool had contributed to mutual understanding (about 31% disagreed) and forced the designers of the container terminal to take into account the interests of other actors (about 23% disagreed).

Dominance of the tool, limitation of creativity, and strategic use of the tool. A number of the expected reverse effects of the tool were also substantiated. During the debriefing, some respondents indicated that the tool had been too detailed and generated too much information on the terminal performance. Other participants, however, indicated that they needed more specific data on specific indicators on which to base their decision. Some respondents stated that the tool dominated the discussion, that the use of the tool was fun but in fact less relevant for stakeholders such as environmentalists and residents. This is substantiated by the fact that about 47% thought that the tool did not pay enough attention to long-term developments, external factors (about 60%), and environmental issues (about 50%).

Moreover, a marked number of respondents seemed to indicate that the drawing elements in the drawing tool somewhat limited the making of a creative design.

Conclusion

The game CONTAINERS ADRIFT proved a well-balanced research and training environment for combining process management and the simulation building block approach. It confirmed that process management is a highly complex activity requiring group facilitation skills, academic insights into interorganizational decision making, and experience with appropriate simulation tools (Vennix, 1996). In the early stage of infrastructure design, stakeholders easily fall into the trap of focusing on content before agreeing on process. This is likely to backfire at later stages of the project. Stakeholders should be consulted and included in setting the agenda and defining the rules and procedures. In the various sessions, the highly conflicting and confusing discussions of the first part of the game eased when consensus was reached about how they were going to design and explore the issues further. Through the conflicts, the participants internalized the design process, and some ground rules were established.

The agreement reached on the process and the opportunity to discuss and visualize their conflicting interests with respect to the container terminal, while using the fast and easy to use simulation tool, led to a more constructive exploration of the issues and solutions.

In our view, the experiment confirmed that a process management approach to decision-making processes needs analytic activities, such as visualization and simulation, to obtain a higher level of (mutual) understanding. Vice versa, process management provides the guidelines and rules for interactive simulations with stakeholders.

The simulation tool developed for the game CONTAINERS ADRIFT was evaluated on a number of relevant characteristics for process management. The evaluation results are promising and show that the tool is fast, easy to work with, contributes to the quality and progress of negotiation, and generates mutual understanding. A limitation of the study, of course, is the fact that the simulation building block-process management approach was tested with students in a game setting. A logical next step is to use and test the tools and approach for the support of real decision making with actual stakeholders. The game experiments have led us to believe that this can be done in two ways.

First, the actual stakeholders facing a real problem or decision-making process can play a game (CONTAINERS ADRIFT or a similar one) before they engage in actual decision making. The game would then function as a metaphor for the real problem and challenges the real stakeholders to reflect on how they want to structure and support their real decision-making process. In this way, the game is a demonstration to (potential) clients and interdependent stakeholders of the (benefits of a) building block-process management approach. It can also trigger negotiations on how and when to use it for real decision making.

Second, a simulation building block tool can be developed that is tailor-made for a real-problem situation. In this case, the process managers of the game are the real consultants, the participants are the real stakeholders, and the outcomes of the procedure are used for real decision making. It is clear that the building blocks should be valid and transparent for the participants. Using it for real life situations implies that even more attention should be paid to the selection, specification, and validation of the building blocks. The client and a selection of stakeholders can and should be engaged in the development process of the tool, for instance by providing and validating information and data underlying the building blocks. This way of working has the following three main advantages: (a) it makes the design of the tool interactive and thereby more transparent and valid, (b) after the building blocks have been defined and the tool has been build, it can be used in a fast and flexible mode with a wider group of stakeholders to support decision making, (c) the building blocks can be adapted or even reused for future sessions concerning the same or similar issues.

Critical questions concerning the validity of the underlying building blocks, the simulation model, or the outcomes can furthermore be recognized as a legitimate, and probably unavoidable, aspect of modeling and simulation for decision support. In other words, when stakeholders start to raise such questions, they are learning about the issue at hand and about simulation in general.

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Igor S. Mayer is an assistant professor of public management at the faculty of Technology, Policy and Management of Delft University of Technology. He has recently edited and coauthored the book Games in a World of Infrastructures: Gaming-simulation for research, learning and intervention *(Eburon, 2002). His activities concerning gaming simulation for clients, education, and research have been brought together in Gymnasion (www.gymnasion.tudelft.nl).*

Wieke Bockstael-Blok has a background in applied physics but now conducts research on transportation and logistical systems. She is an assistant professor of systems engineering at the faculty of Technology, Policy and Management of Delft University of Technology.

Edwin C. Valentin is a PhD researcher with the faculty of Technology, Policy and Management, where he conducts research on simulation building blocks.

ADDRESSES: ISM: Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, PO Box 5015, 2600 GA Delft, the Netherlands; telephone: +31(0) 15 2787185; fax: +31 (0) 15 2783429; e-mail: i.s.mayer@tbm.tudelft.nl. WB: Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, PO Box 5015, 2600 GA Delft, the Netherlands; telephone: +31 (0) 15 2787185; fax: +31 (0) 15 2786363; e-mail: wiekeb@tbm.tudelft.nl. ECV: Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, PO Box 5015, 2600 GA Delft, the Netherlands; telephone: +31(0) 15 2783440; fax: +31 (0) 15 2783429; e-mail: edwinv@tbm.tudelft.nl.