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APPROACH FOR MODELLING OF LARGE MARITIME INFRASTRUCTURE SYSTEMS

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ABSTRACT

Simulation studies for large infrastructure systems often consists of a large number of experiments. Performing all experiments, and the required adjustments to simulation models, is time consuming. In addition it is difficult to keep track of all performed experiments and compare the outcome of these experiments. These issues can be clearly identified by observing a simulation study at the port of Tanger which is performed in the traditional way. In this paper we describe an alternative approach for performing simulation studies regarding large maritime infrastructure systems. This approach includes the use of a domain specific template developed in the simulation environment Arena and a database tool that enables creation, evaluation and managing simulation experiments.

1 INTRODUCTION

Large infrastructure systems are often modeled using discrete event simulation models to enable evaluation of the future performance. These systems require large investments, therefore simulation models are used to show the service levels that are provided under different scenarios and infrastructure decision. Examples of large infrastructure systems that have been modeled using discrete event simulation are railways for New York Freight Tunnel (Kulick, 2004), subways for London Underground (Mayo et al, 2003), airplane runways (Holden and Wieland, 2003) and container terminals (Duinkerken et al 2002).

Simulation studies that are performed to support design of large infrastructure systems can be characterized by the following items (Wynne, 1988):

1. Scenarios run far into the future, typically 5 to 15 years from the moment of performing the simulation study. The forecasts of the use of the system therefore vary between wide minimum and maximum values.
2. Fluctuation of use over the period of time that is simulated. The use of the infrastructure often differs between summer or winter, week days or weekend and morning or afternoon.
3. Events outside the influence of the problem owner have effects to the performance and service level that the infrastructure can offer. For example, weather changes the possible use of runways at airports and tide changes speed and accessibility of ships in ports.
4. Problem owners define new alternatives in infrastructure as simulation studies proceed. The new insights of problem owners, partly fed by the outcome of the simulation study, enable the problem owner to define alternatives that overcome the issues and bottlenecks that appeared in the first experiments that have been performed during the simulation study.
5. Green field situation where 'sky is the limit'. If bottlenecks appear in an initial design, the problem owner has a wide range of solutions that can be applied. This means that the initial simulation model often completely needs to be rebuild or reconfigured to identify whether a solution is feasible.
6. Involvement of multiple parties resulting in a complex decision structure in the detailed design phase. Some of the parties involved in the design of infrastructure are commercial users of the infrastructure with their demands on capacity and service levels, local government bodies with demands regarding the layout of the infrastructure, ministry officials with demands on capacity use reliability and economy.

These characteristics result that a wide range of scenarios is performed during a simulation study for large infrastructure systems. The large number of experiments that are performed in these simulation studies results in two problems: 1) changing the simulation model over and over again for new experiments is a complex and time consuming task; 2) keep track of performed scenarios for efficient analyses is difficult.

In the simulation study of these large infrastructure projects domain experts are often hiring simulation experts to perform a part of the simulation work. Domain experts do not develop their own simulation models, but hire the simulation experts to develop simulation models that they can use to perform simulation experiments. These simulation models are constructed in such a way that domain experts can perform the necessary experiments and retrieve the data out of the simulation model that they are interested in.

Within this paper we focus ourselves to the domain of maritime infrastructure. This domain is particular interesting, because of influences of new technologies, i.e. new types of ships, and the growing competition between different ports. In section 2 more specificities are mentioned. With the knowledge of simulation of large infrastructure projects and specifically maritime infrastructure we have performed a simulation study at the port of Tanger (section 3). This project is described as an example of a project that is performed by a project team in which simulation experts and domain experts worked closely together. Simulation experts developed a simulation model of the port of Tanger and domain experts used the simulation model to perform experiments.

All of the mentioned characteristics applied for this simulation study. As a result the domain experts performed a lot of simulation experiments and they had difficulties analyzing and comparing the different scenarios. In addition they needed structural adjustments to the simulation model, which could only be performed by the simulation experts and not by the domain experts.

We assume that domain experts would apply simulation studies more effectively if these domain experts would be better supported in their simulation study. This requires that domain experts are better capable of adjusting the simulation model and managing their simulation experiments. In section 4 we propose a new approach for performing simulation studies to increase the effectiveness of domain experts and their capability of performing their own simulation experiments. This approach uses the technology of a domain specific simulation environment and a database tool for managing the data of individual simulation experiments.

Section 5 describes a simulation study for the Canal Seine Nord. This simulation study is performed following the new approach and by applying the introduced tools, i.e. the domain specific simulation environment for maritime simulations and the database tool for managing simulation experiments.

Finally in section 6 of this paper we present some conclusions of the use of the new approach and tools. This conclusion will provide answer to the question whether simulation studies for maritime infrastructure can be performed qualitatively by domain experts without time consuming interference of simulation consultants.

2 SIMULATION OF MARITIME INFRASTRUCTURE SYSTEMS

Each infrastructure system has its unique characteristics. These characteristics result in slightly different focus in simulation studies performed for these type of infrastructure systems. Simulation studies of maritime infrastructure systems differ from simulation studies of other types infrastructure systems due to the following characteristics:

- System is hard to extend once in operation, for example a lock cannot be closed for a period of months to extend it;
- Economy of scale and standardization in freight thrives the industry, for example, the use of containers and the continuing growth of container ships;
- Geographical environment has strong effects to the performance of the system, for example, wind and tide that block access to ports.

Within maritime simulation studies the common focus to freight transportation with ships is using restricted water infrastructure. The restrictions in the infrastructure are the height of bridges, the size of locks and the width of a canal.

Domain experts apply simulation models in their design process to gather insight how the characteristics of ships in the fleet occupy the restricted infrastructure. A fleet of ships consisting of a large percentage of high ships will have different occupancy of a bridge than a fleet with a majority of flat ships. Similar occupancies can be defined based on the ship characteristics width (in a narrow canal), length (in a lock), rotation speed (at a junction in a harbor) or weight (occupying tug boats).

The questions that problem owners face is how they can ensure a service level to the expected fleet of ships that will use the restricted infrastructure. The answer to this question should be an ideal mix between a certain expected use (the fleet of ships in a couple of years from now) and the restrictions caused by infrastructure. The problem owners can decide to invest in the infrastructure to remove some restrictions or invest in control mechanisms and procedures. Examples of investments are larger locks, higher bridges or wider canals. Examples of control mechanisms and procedures to manage the flow of freight ships are priority mechanisms of types of ships, signaling of ships to a bridge for moment of opening or traffic light construction for narrow water canals.

The process of performing simulation study for maritime infrastructure systems is comparable with a simulation study as described by Banks (1999). A main difference is that the size of a project and the investments easily validate the decision to hire professional simulation experts to develop the model and perform some simulation experiments.

Figure 1 shows the process of performing a simulation study for maritime infrastructure in which the role of the domain expert and the simulation expert is clearly separated. This separation results in a lot of communication between the involved actors and in double feedback loops to adjust the simulation model or the collected data. These feedback loops will be followed several times in simulation studies for maritime infrastructure, because the domain experts will identify alternatives during the project.

3 EXAMPLE OF TRADITIONAL SIMULATION PROJECT: PORT OF TANGER MED

The port of Tanger (Morocco) will be a new port for mainly Roll on and Roll off ships (RoRo). This port will in the future provide services to an increasing number of container ships. The increasing number of container ships can only be managed if the port will be extended with additional quays and deepened for container ships. This change to the port requires a large investment of the port authorities and therefore is decided to perform a simulation study to evaluate different scenarios of number of quays for different types of ships. The port authorities hired the engineering company Sogreah as domain experts and the company Systems Navigator as simulation experts to perform a simulation study following the process of Figure 1.

3.1 The Simulation Study

The scope of the simulation model consists of ships that enter to the port via a restricted water block that allows ships from one direction at a time. All ships that want to load or unload in the port of Tanger have to enter through this restricted water block. The ships claim a quay position before they are entitled to move onto the restricted water block to make sure they can leave the water block when they reach the end. The ships also request to use one or two of the restricted tug ships, depending on ship size and weather conditions.

The simulation model has been developed by simulation experts in the generic simulation environment Arena. The simulation experts and the domain experts have together determined the level of reduction, the scope of the model, input parameters and the key performance indicators. The simulation model is extended with a visualization like shown in Figure 2.

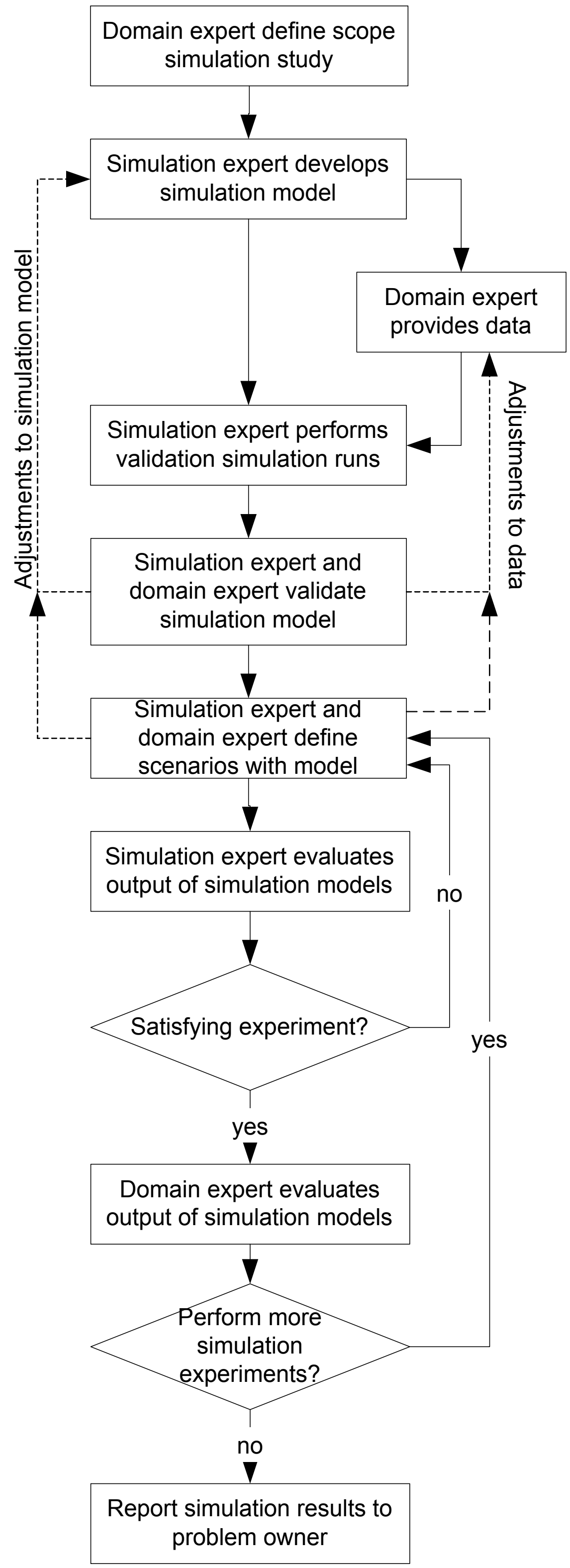

Figure 1: Process of Simulation Study for Maritime Infrastructure

The restricted access to the port is visualized by the two water blocks in the middle of figure 1. One ship is leaving the port and restricts any other ship from entering from the sea or leaving from a quay at the same moment. Therefore the ship at the container quay is represented in the color of waiting before departure.

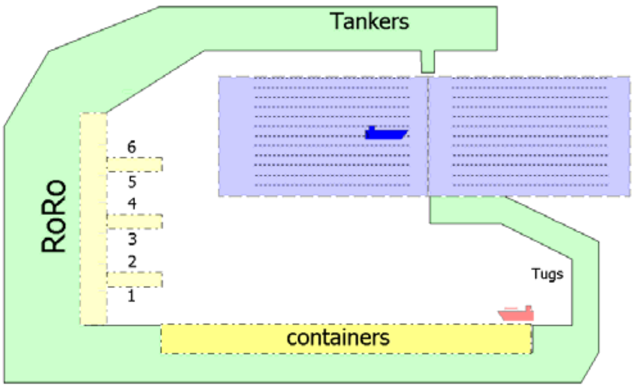

Figure 2: Animation of Port of Tanger MED, Morocco

The animation of the simulation model shows the port of Tanger with 6 RoRo quays and one quay for container ships. In later simulation experiments the model has been adjusted for multiple container quays and less RoRo quays. Other experiments that have been performed with the simulation model included different process durations for loading and unloading of ships, different number of tug ships available and different types of ships. The domain experts wanted to do as many experiments as possible by themselves. For example, adjusting the number of RoRo ships that arrive per day was a parameter they could easily manipulate themselves. Figure 3 shows a small part of the simulation model where the domain experts could change input values for the simulation experiments.

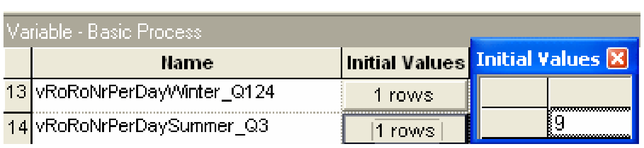

Figure 3: Some of the Variables to be Adjusted by the Domain Expert

Changes to the layout could not be adjusted with the same ease of use as setting parameters. The simulation model has been returned several times to the simulation expert to change the layout as it was modeled in the simulation model. This happened in line with the process description of figure 1, minor changes could be performed by the domain expert, but major adjustments like a new RoRo quay or dividing the container quay in two parts required changes by the simulation expert.

3.2 Remarks About the Simulation Study

The simulation project of Tanger was a success and the problem owners in Morocco where satisfied with the outcome. They gathered insight in the fleet of ships to handle in the port and the optimum infrastructure taking into account tide and wind. However, the expectations of the problem owner that the domain expert would perform all changes to the simulation model to realize experiments could not be matched. As a result the project had a longer lead time and higher costs.

A second remark to the performed simulation study is the management over large amount of data provided by each of the individual simulation experiments. The simulation model provided detailed statistics about the number of ships, the wait time of ships, the utilization of quays and the occupancy of the restricted water blocks. A small change to the number of ships or the speed of the tug boats provided the domain experts almost with an overload of data to be analyzed. Simulation projects of infrastructure systems can be characterized by a large amount of simulation experiments, but generic simulation environments like Arena do not include satisfactory tools and methodologies of managing the experiments and gather the insights in the effects of scenarios in an easy way. In this simulation study print outs have been made of the results of each simulation experiment. Smart naming conventions have been used to identify which parameters have been used to result into the outcome, but the different infrastructure layouts, the different scenarios for number ships, the different speeds for tug boats and the different process durations made it complex for domain experts and simulation experts to keep track on what was done and what not. In the end a lot of the experiments have been performed once more to make sure the settings of the simulation model were as expected. These additional activities were time consuming and extended the lead time of the simulation project.

3.3 Challenges Simulation Studies for Maritime Systems

Domain experts had difficulty to perform all tasks in the simulation study for the port of Tanger. The first issue was the model development, the second issue was managing simulation experiments.

The main simulation model development has been done by simulation experts and also later changes have been made by these simulation experts. The development of the simulation model by simulation experts saved the domain experts in the Tanger project time, but also created a dependency on those simulation experts. The model needed to be transferred from the domain expert to the simulation expert for major adjustments. This transferring of models between developer and user is time consuming and influences the project lead time.

If domain experts can develop their own simulation model, they also can make adjustments themselves. In such a situation the domain experts will be less dependent on simulation experts. Unfortunately, domain experts are not sufficiently skilled to develop a simulation model in a general purpose simulation environment like Arena. The domain expert is used to think in concepts like ship, water block and quay. This is completely different from the concepts and controls such as resource, queue and entity as provided by generic simulation environments.

The simulation model of the port of Tanger provided too much data. The domain expert looses its way in the outcome of the simulation models. If domain experts will be capable of managing the scenarios and the performance indicators of a simulation model, they can perform better evaluation of experiments. Tools provided by Arena like Process Analyzer and OptQuest enable automating the process of running a lot of simulation experiments, but these tools are limited in the number of performance indicators that can be compared. In some simulation studies time and money is available for a tailor made data management tool. Unfortunately, within the Tanger project developing a tailored solution was not feasible.

The issues observed in the simulation study trigger two challenges for further simulation studies in the domain of maritime infrastructure:

A) Enable domain experts to develop valid simulation models
B) Enable domain experts to manage input and output of large amount of simulation experiments

4 NEW APPROACH FOR SIMULATION OF MARITIME INFRASTRUCTURE

4.1 Requirements Solution

The challenges that are identified in the previous section can be tackled by tools tailored to the domain of maritime infrastructure and a new approach how to apply these tools. These tools and approach should match the following requirements:

1. Development of the simulation model should occur in an environment that represents maritime infrastructure instead of resources and queues.
2. Maritime infrastructure elements should be easily configurable
3. Input and output of scenarios should stay together
4. Domain expert should be able to retrieve overview of different scenarios
5. Domain expert should be able to visualize the outcome of several scenarios in one screen or graph

4.2 Solution Tools

Domain experts that want to use simulation but are not up to speed with any generic simulation environment are often supported with building blocks dedicated to the domain in which they operate. The simulation models can then be instantiated from domain specific building blocks instead of model constructs like a resource or a queue. A simulation environment that consists of building blocks for one domain is called a domain specific simulation environment (Valentin and Verbraeck, 2002).

Domain experts that use a domain specific simulation environment can develop a simulation model in concepts and terminology of their domain. They do not have to bother about complex rules and detailed use of resources, because the building blocks for the specific domain incorporate these issues for them. Domain experts that develop their own simulation model can also adjust the model for experimentation and thus they will be better in control on the project and therefore they do not need the services of simulation experts within the project.

A lot of model developers build interfaces on top of their model to enable domain experts to perform simulation experiments more easy. Within these interfaces domain experts can adjust a limited range of model variables. These interfaces often do not manage the input data, but only feed them directly into the simulation model. These interfaces also do not manage the outcome of simulation models. The outcome is briefly represented in the reports of the simulation environment and then discharged. The only feasible solution is to develop a database system in which the data is prepared for a simulation scenario and the output data stored. If this database system is developed to connect to the building blocks of a domain specific simulation environment, the gain is double, because key important performance indicators can receive a higher importance.

4.2.1 Templates for Large Infrastructure Systems

A domain specific template is a set of model constructs that enable a domain expert to easily instantiate a simulation model of a system within a certain domain. The model developer can use modules that represent elements that can be observed in real-life, rather than abstract things like a resource or a queue. Rail networks (Hooghiemstra and Teunisse, 1999) and container terminals (Mayer et al, 2004) are examples of domains for large infrastructure systems where templates exist.

A template is powerful, but not sufficient to support domain experts to be able to develop their own simulation models. The support for domain experts is more completed if the template is provided with a range of small simulation models that have been developed to show the use of modules in the template. These small simulation models can be used in a training document that describes how the small model should be adjusted. For example, a small model with a quay, a container crane and arriving ships shows the effect of the unloading time of container cranes in the template for container terminals (Mayer et al, 2004).

These small models enable the domain experts to understand and trust the template. Domain experts can develop their own simulation models and make their own adjustments. The changes that domain experts can perform to the simulation models are no longer restricted to loading or unloading times of ships, like in the Tanger model, but also the complex adjustments to infrastructure, which are becoming simple thanks to the modules of the template.

A template has been developed to represent the typical elements of a maritime infrastructure system. Figure 4shows the modules that are part of this template.

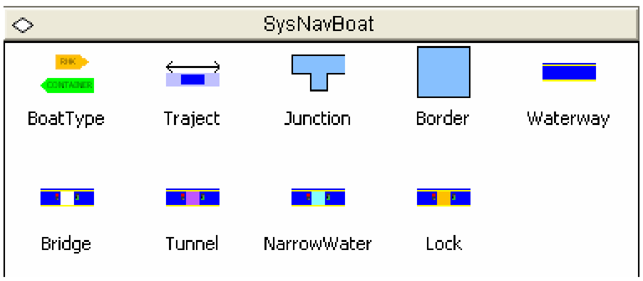

Figure 4: Template for Modeling Maritime Infrastructure

In this template several ship types can be defined. These ships use infrastructure to move from an origin to a destination. The infrastructure is defined by connecting different modules together. Figure 5 is a small example of the infrastructure that can be defined using the different modules. At the left side is a border, then a ship moves through a waterway, enters a lock and moves down, continues with a new waterway and reaches a destination.

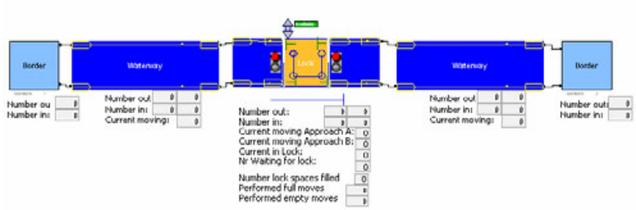

Figure 5: Example Simulation Model

The modules shown in figure 4 enable the construction of much more complex networks of waterways. A network can include different trajectories, junctions, ports, bridges and locks.

The domain expert that develops simulation models using this template can perform all kinds of experiments that are typical for maritime infrastructure. For example, different infrastructure networks, different number of ships that arrive per day and different tiding or weather conditions. The template already supports domain experts in performing the simulation study. Within simulation studies that use domain specific templates can be observed that many more experiments are performed. Compared to simulation models developed with generic simulation environments, it is now much easier for a model developer to adjust a simulation model. This increases the complexity of managing scenarios and the ability to compare different scenarios together.

4.2.2 Scenario Navigator

We have developed a database tool that manage the input and output data and communicates this data with simulation models developed for the domain specific simulation environment for maritime infrastructure projects. **Figure 6** shows the main process that is performed within this database tool. Input data for scenarios is prepared, this data is fed into a simulation model of a maritime simulation and the simulation model stores its output data. This output data of several scenarios can then be viewed by domain experts using different graphical representations. We call this tool Scenario Navigator, because it allows us to navigate through different scenarios of a system.

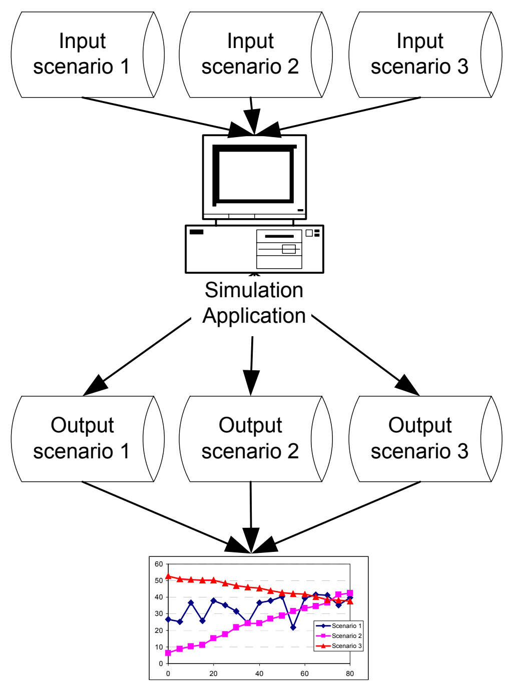

Figure 6: Process Experimenting with Scenario Navigator

Within the Scenario Navigator the domain experts can choose what data to represent. They will only focus on the key performance indicators that they are interested in at that moment in time. However, as their insights change, they might be interested in different output. All data of a simulation project remains available and the domain expert can thus easily review specific output of one or more performed scenarios.

The history of performed scenarios enables domain experts also to evaluate whether they already performed certain experiments. This saves time in rerunning experiments and provides a good overview of the data that is available for future simulation experiments to be performed.

Figure 7 shows a screen dump of the Scenario Navigator with an example outcome for the Tanger project. The graph at the right side of this figure shows the utilization of different quays in different scenarios. This is only a small part of all the data that is available in the database. Users of the Scenario Navigator have to select the data they want to represent. These users can navigate through the performed scenarios and through the collected statistics what they want to see. The screen for selecting the desired statistics for representation is shown at the left side of the figure.

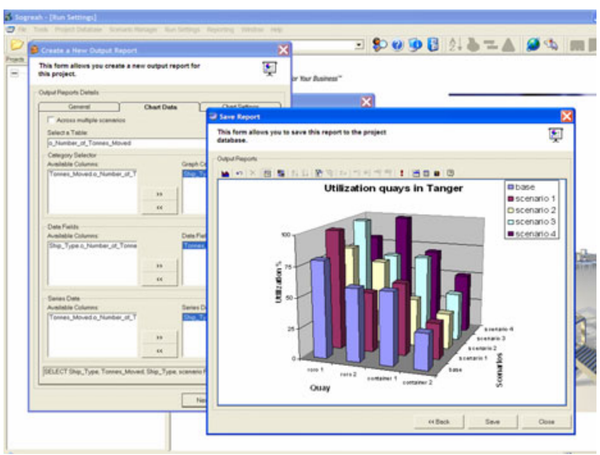

Figure 7: Screenshot Scenario Navigator Reports

4.3 Approach Simulation Study with Template and Scenario Navigator

The use of a domain specific simulation environment and the Scenario Navigator tool change the process of performing a simulation study for maritime infrastructure projects. The changes mainly regard the collection of data and adjusting the simulation model for experimentations. **Figure 8** shows how the process of a simulation study is performed when a domain specific simulation environment for maritime infrastructure can be used in combination with the Scenario Navigator.

The data collection can start directly after the scope of the simulation study is determined. The building blocks of the domain specific simulation environment for maritime infrastructure set the definition of data that is needed. Further the data can directly be entered into the Scenario Navigator where it will be managed and controlled before a scenario will be started. The scenarios can be; validation of the simulation model with extreme values, the current situation or one of the many future layout alternatives.

More data will be stored into the Scenario Navigator tool. Therefore less adjustments need to be made to the simulation model of the maritime infrastructure project. This is represented by removing the feedback loops. Changes in the Scenario Navigator tool need to be made in any experiment, therefore feedback to data entering does not make sense. This reduces the complexity of the process and enables domain experts to better predict how much longer a simulation study will take before the reports can be produced.

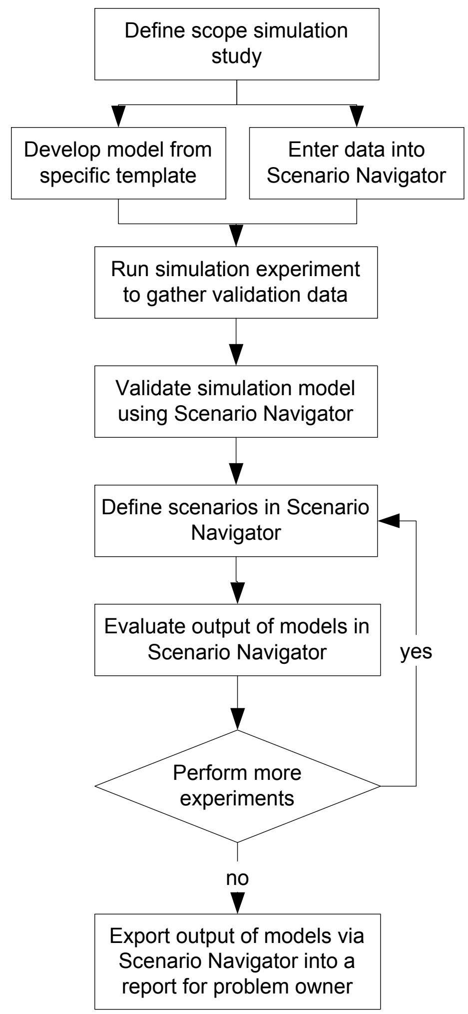

Figure 8: Process of Performing Simulation Study using Template and Scenario Navigator

Finally when enough simulation experiments have been performed and the domain experts are satisfied, it will be easier to populate final reports. The graphs that have been used in the analyzing and comparing phase, figure 7, can now also be used to add to the reports of a simulation study. Simply cut and paste into a powerpoint presentation or word report.

5 EXAMPLE OF APPLYING THE NEW APPROACH: CANAL SEINE NORD

The France government has defined 50 infrastructure projects that should be realized before 2025. One of these projects is a canal to connect freight transport from Paris to Belgium, also known as Canal Seine Nord. This canal will be over 100 kilometers long and contains 6 to 8 locks. The total project costs are estimated to 2.6 billion euros and will be financed by the France government and the European Union. At the beginning of the simulation study several infrastructure alternatives were available regarding the number of locks and the sizes of locks.

This project has been a first step into where the described approach has been used. The domain expert has used the modules of the template to instantiate simulation models of the proposed layouts. These simulation models have been experimented with different configurations of ships, different number of ships arriving and different policies for the operation of locks and bridges.

A part of the output of the simulation model has been analyzed using the Scenario Navigator and within the Scenario Navigator the new experiments have been defined. In simulation studies for maritime infrastructure projects that follow the normal approach of a simulation study the number of experiments is already high. We observed that with the preliminary use of the Scenario Navigator the number of simulation experiments grows even further, because it is easier for a domain expert to create new scenarios and easier to keep track on the performed scenarios.

All experiments that have been performed during the simulation project for Canal Seine Nord have enabled the problem owner to redefine the design of the canal. The number of locks have been adjusted and also some controls have been defined when a lock should be opened. The simulation models enabled the problem owners to observe and understand the number of lock movements and prepare counter actions for empty lock movements that occur during a day.

6 CONCLUSIONS AND FUTURE WORK

The simulation project that has been performed for the Canal Seine Nord has been successful. The domain experts have been able to make their own adjustments to the simulation model using the domain specific template. The Scenario Navigator enabled them to keep track of their experiments and easily create additional experiments and new scenarios.

Based on the experiences with the domain specific template for maritime infrastructure and the Scenario Navigator in the Canal Seine Nord new projects have been initiated in which the same approach has been used. One of the projects is evaluation of a lock in the Netherlands to support domain experts of the Dutch government in their decision process for a new lock on the river Maas.

We expect that the advantages that have been achieved with the domain specific template and the Scenario Navigator can also be achieved in other domains than maritime infrastructure. Further research will show the applicability of the described approach and tools in domains like railways , container terminals, hospitals and supply chains.

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REFERENCES

Banks, J. 1999. Introduction to simulation In *Proceedings of the 1999 Winter Simulation Conference*, P.A. Farrington; H.B. Nembhard; D.T. Sturrock ; G.W. Evans (Eds.) 7-13. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Duinkerken, M.B.; J.A. Ottjes; G.Lodewijks. 2002. The application of distributed simulation in TOMAS: redesigning a complex transportation model. In *Proceedings of the 2002 Winter Simulation Conference*, E. Yücesan; C.H. Chen; J.L. Snowdon; J.M. Charnes (Eds.) 1207-1213. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Holden, T.S.; F. Wieland. 2003. Runway schedule determination by simulation optimization. In *Proceedings of the 2003 Winter Simulation Conference*, S. Chick; P.J. Sanchez; D. Ferrin; D.J. Morrice (Eds.) 1670-1676. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Kulick; B.C. 2004. The use of simulation to support major transportation planning decisions. In *Proceedings of the 2004 Winter Simulation Conference*, R.G. Ingalls; M.D. Rossetti; J. S. Smith; B.A. Peters (Eds.) 1345-1348. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Mayer, I.S.; W.Bockstael-Blok; E.C. Valentin. 2004. Containers a Drift: Visualization-simulation of an inland container terminal design, *Simulation and Gaming,* 35 (1): 29-52.

Mayo, D.D.; W.J.Dalton; M.J.Callaghan. 2003. Steering strategic decisions at london underground: evaluating management options with system dynamics. In *Proceedings of the 2003 Winter Simulation Conference*, S. Chick; P.J. Sanchez; D. Ferrin; D.J. Morrice (Eds.) 1578-1584. Piscataway, NJ: Institute of Electrical and Electronics Engineers.

Valentin, E.C.; A. Verbraeck. 2002. Simulation using building blocks. In *Proceedings conference on AI,* *Simulation and Planning*, F.J. Barros; N .Giambiasi (Eds.) 65-712.

Wynne, B. 1988. Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding, *Social Studies of Science*, 18(1): 147-167.

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