

# THE USE OF A TEMPLATE-BASED METHODOLOGY IN THE SIMULATION OF A NEW CARGO TRACK FROM ROTTERDAM HARBOR TO GERMANY

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## ABSTRACT

With large and complex simulation studies one of the most crucial success factors is the way you model reality, followed by choosing the right level of abstraction. Designing a modeling approach in these studies is therefore as important as building the actual model itself. The following paper describes a methodology, using template technology, which already has been successfully employed in large and complex simulation studies. This paper uses a rail capacity study as a vehicle to present the methodology as used in a commercial project.

## 1 THE BETUWERROUTE CAPACITY STUDY

### 1.1 Background

The Dutch rail net is one of the most heavily used nets in the world. With 5000 trains a day, running on 2800 km track, on only 37,000 sq. km., the Netherlands has also one of the most dense rail systems in the world (according to Railned, the Dutch organization for rail capacity planning).

The Netherlands is one of the few European countries which is actually building new track for cargo transport. This new track, called the Betuweroute, will link Rotterdam harbor, in most aspects the largest harbor in the world, direct to one of her biggest clients, the Ruhr area, industrial heartland of Germany. The Betuweroute project will enhance the least used of the three transport modalities between the harbor and the Ruhr namely river barges, trucks and cargo trains. The new track will be exclusively devoted to cargo trains, whereas previously cargo trains used the same network as passenger traffic.

The Betuweroute project team needed proof that the capacity of the complete new cargo line would be sufficient to meet the requirements. They also needed a good way to communicate the results to the government and needed the results in a limited time period.

### 1.2 The Problem

Simulation has been used for many years for rail simulation. The Netherlands Railways actually designed or adapted at least three simulation tools (DITEM, CAPSIM, UX-SIMU) themselves. Together with the use of some publicly available simulation packages the use of simulation in many Dutch rail simulation projects has been, to our knowledge, on a very detailed technical level. This often resulted in projects which needed a lot of time and effort. This made that customers regarded simulation studies only useful for well known rail systems of limited size.

Imagine a new line which spans a country. Even if that country is as small as The Netherlands, the amount of detailed data required, often unavailable anyway, increases the failure rate of the simulation project seriously. This, together with the limited time available, were enough reasons not to use simulation in the traditional way as described above.

This paper describes the methodology used in the Betuweroute capacity study which was undertaken by Holland Railconsult (Utrecht, The Netherlands), the former engineering department of the Netherlands Railways, and Incontrol Simulation Technology (Maarssen, The Netherlands), a business unit of Incontrol Business Engineers which specializes in discrete event simulation.

### 1.3 Project Goals

The Betuweroute capacity study had to give an answer to the following questions:

*Is the capacity of the Betuweroute enough to handle the expected amount of cargo traffic in 2010? Where are the bottlenecks and what are the possible delays?*

What is the capacity of a rail line? The theoretical capacity is easily calculated based on train separation and speed of the trains. With reasonable speed and

common train behavior it should be possible to put more than 50 trains per hour over one line. If resources are almost unlimited and control almost perfect we can push the real capacity close to the theoretical limit. An example of that is the use of the Berlin air strips during the air supply bridge to Berlin at one time during the cold war. With very good planning it was possible to use the airstrips close to 100% and let aircraft land and take-off within minutes from each other without problems.

What are the specific problems in this situation?

- Trains have different starting locations and different destinations, sometimes blocking the line when coming in or going out.
- Even if a perfect timetable is possible, variations will disturb entry times on the line which hinder other trains
- Trains are different from each other and have other characteristics influencing the travel time, sometimes blocking other trains.

The real capacity of a rail line is therefore not easily calculated using mathematics. This was the main reason why discrete event simulation was used to analyze the capacity.

The project should also leave behind a tool with which the Betuweroute management team could experiment with different cargo traffic characteristics and different infrastructure layouts.

Constraints in this project were:

- There was limited amount of time available for the project.
- Very limited detailed information was available about the specifications of the new rail line.
- The model should be suitable for use in various types of presentations.
- Model and underlying tool should be re-usable for various analyses by the client.
- The subject of study was very large and could possibly result in a model where verification/validation and maintenance is very hard to handle.

## 2 THE METHODOLOGY USED

The description of the methodology used in Betuweroute study is structured by looking at the ways of thinking, managing, working, modeling and supporting behind the approach which was taken. This structuring is a framework in which methodologies can be compared and evaluated (Eijck, 1996):

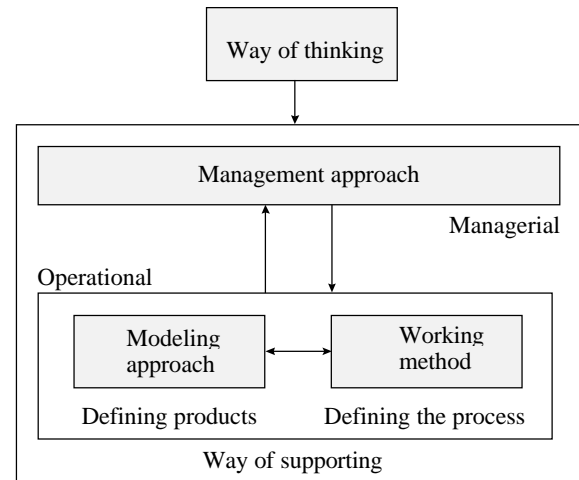


Figure 1: An Analytical Framework for Design Methodologies

- The way of thinking: the basic paradigm/philosophy which was used.
- The working method: the steps and deliverables in the project.
- The modeling approach: the concepts used to abstract reality in models with a certain structure and specific constraints.
- The way of supporting: the various tools used.
- The management approach: the methods and techniques used in managing/controlling the project.

### 2.1 The Way Of Thinking

The constraints of the project mentioned above resulted in the following conclusions after an initial study:

- a project result would be best found with minimal modeling effort

The level of abstraction which is chosen in a simulation study is directly related to the time and effort needed in the creation of the model. The Betuweroute was still on the planning board, so a lot of information needed for a high degree of detail was not available. Choosing the highest level of abstraction and thus the least modeling effort, was needed to negate the lack of detailed information.

- maximum certainty in the assumptions is needed to make results useful

When detailed information is missing, assumptions have to be made. Conclusions from a simulation study are only valid when the assumptions are valid. Therefore when making assumptions extra care should be taken to

select worst-case values. If these lead to a satisfying outcome, this outcome will be feasible in reality and can therefore form the basis on which the client will make his decisions.

In the Betuweroute project worst-case assumptions were for example the arrival of trains on the track and train characteristics. The arrival pattern was based on expected peak traffic only and the characteristics of the least performing trains were used as a standard for all trains. If the capacity of the Betuweroute would be sufficient under these circumstances, it would certainly be in reality.

## 2.2 The Working Method

When working on a high level of abstraction, but with maximum certainty, the working method is as follows:

Use a top-down modeling approach when designing the Betuweroute model. Keep the model on the highest level of abstraction and when using a worst-case approach it is still possible for the rail line to handle the cargo traffic, the result is positive.

When the result is questionable and it is not sure whether there is enough capacity, zoom in on the problem spot, and add more detail or use other means to analyze that sub-system. With this working method, problem areas within the rail line are identified as individual sub-projects for which a more detailed and less worst-case approach can be defined. Zooming in on these sub-projects will stop when either results are now positive or the maximum level of detail is reached. Results of these sub-projects can be incorporated back in the higher-level model.

In case of the Betuweroute, this working method gave the client some fast results, even on the high level of abstraction used. First results indicated with only minimum effort and time which of the problem areas needed further investigation. For example more detailed simulation projects were initiated for some of the freight yards. No more time was wasted in investigating non-problem areas.

## 2.3 The Modeling Approach

The modeling approach can be seen as designing a specific way of modeling for a certain application area. Every individual modeling approach has than its own terminology to describe the problem-area, generic structures to build a model, and performance-indicators to value the outcomes of the simulation study.

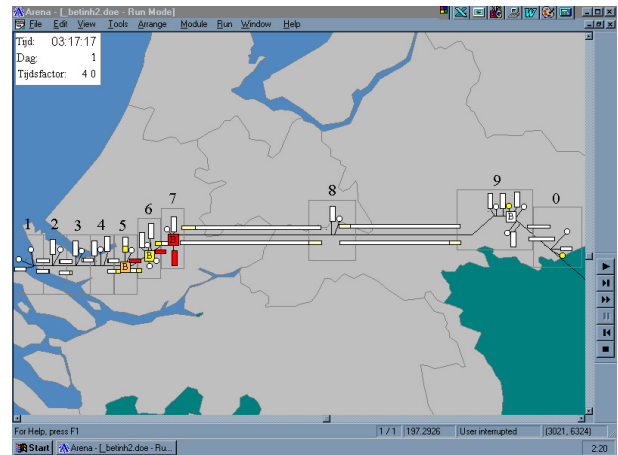


Figure 2: Example of Dynamic Visual Output of the Model on the Highest Level of Abstraction

In the case of rail simulation, people will usually model rail systems with distances, speed and minimum separation distance expressed in discrete rail “blocks”. Modeling those rail “blocks” however implies choosing a specific, although much used, safety system. For a new line such a specific safety system might not have yet been chosen.

Highest level of abstraction for example means, instead of taking distance and speed that a train travels, using a certain amount of traveling time until it can possibly encounter something with which it might interact.

The safety system can be modeled in an abstract way by defining a minimum time a train will wait until it follows another. In this case it is not important anymore exactly which safety system will be used in the future.

With this simplification of how trains behave, a way of modeling was chosen. This is described below.

### *The pipe:*

In a pipe, trains are not hindered and take a certain amount of time to travel through. Trains have a minimum safety time with which they follow another into or out of a pipe, without the possibility of overtaking. There is a maximum number of trains in the pipe at any time.

### *The node:*

A point in the infrastructure where a train might encounter something for which it will have to wait. The node is also a position where trains can enter or exit the rail line.

The two major performance indicators are directly related to the goal, i.e., to come up with both bottlenecks and possible delay times and are:

1. the relation between a possible minimum traveling time against the realized traveling time
2. the utilization of the nodes/pipes.

With this first very high level of abstraction the study started and the model of the Betuweroute was defined in terms of the above described components. Most of the time-related parameters were separately defined using existing tools in the rail community, other parameters were much easier gathered using the worst-case approach.

## 2.4 Way Of Supporting

Defining high level objects such as the pipe and the node does not have to stop on the drawing board. When using a tool which supports the building of software components in a library or ‘template’ these high level objects can be constructed and put in a template to be used when finally constructing the model.

### *What is a template?*

A template is a collection of user-defined, re-usable modeling “building blocks”. Building blocks are created by programming their functionality, interface, animation and performance indicators in a suitable simulation environment. When high level objects, such as the “pipe” and the “node” in the Betuweroute project, can be successfully brought “alive” by these building blocks in a template, such a template becomes the embodiment of a specific modeling approach, rather than only a smart way of re-using program code.

The use of templates has the following advantages:

- it speeds up the time to build a model significantly because concepts and functionality can be more easily re-used;
- there is a separation between design and implementation; the needed complexity, once built and tested, is hidden from the user of the template, making it easier for that user to concentrate on functional instead of technical problems;
- verification of models is easier because of easier verification of the separate “building blocks;”
- experimentation is much easier because either parameters are changed on easy-to-find spots or high-level building blocks are added instead of changing low-level code;
- it becomes possible for many more people to build an actual model with a template without the need for extensive training in simulation or a specific simulation environment;

- the use of a template reduces the risk of having too much detail in the model because of the dedicated functionality of the template.

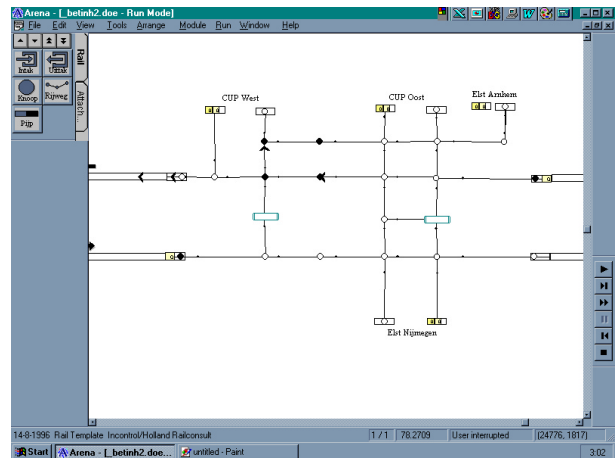


Figure 3: Part of the Animation of the Model, including the Modules of the Template used for the Betuweroute Capacity Study

For the model of the Betuweroute a template was built in the Arena simulation environment (Pegden, Shannon, Sadowski 1995). To the writer’s knowledge Arena has been one of the first and foremost simulation environments to incorporate the technology of using templates. There are Arena templates commercially available for specific application areas such as Call Centres, Wafer Fabrication and High Speed Packaging.

## 2.5 The Management Approach

The working method and the modeling approach will be most successful when integrated in a controlled interactive process with the client and their domain experts.

The combination of a top-down design and using a maximum certainty or worst-case approach means extensive communication with the client about acceptance of the level of abstraction and to define worst-case parameters. Milestones will have to be defined to decide about the possible start and results of specific sub-projects to save as much valuable time as possible.

Every sub-project gives an opportunity to give the client feed-back about progress of the study and is an excellent time to decide which problem areas might need extra work. In this way the result of the study will be very close to what the client actually wants.

The modeling approach, in combination with the way of supporting, is also an important management aspect. The model becomes much more maintainable because

large and complex structures are reduced to the basic modeling concepts in the form of building blocks. During Betuweroute project it became clear that the client more readily understood and accepted the model and its results because the building blocks related easily to his domain.

### 3 RESULTS

The fundamental result of the project was that it gave first insight in the dynamic behavior of the Betuweroute in a very short period of time. It also revealed some potential problem-areas which needed further investigation. The presentation of the first results was very well received by the client.

The authors are convinced that a simulation model of the Betuweroute could not have been built in the same time without using a template created on the basis of the modeling approach as described above.

The Betuweroute capacity study resulted in what is now called the Rail Template. After this project the template has been used in several other projects regarding rail infrastructure capacity. It also proved to have enough flexibility to be used successfully in more detailed studies regarding the Betuweroute concentrating on the potential problem areas indicated by the original study.

The Betuweroute capacity study changed the perspective on simulation of the people from the Dutch rail community involved. It changed the perspective that rail simulation was time consuming and difficult to comprehend by non-simulation experts.

### 4 CONCLUSIONS

The template-based methodology using top-down design combined with a maximum certainty approach has proved to be successful in a study of a new rail cargo line connecting the Rotterdam harbor with its biggest client, the German Ruhr area. The approach is received very well by the Betuweroute management team, not in the least because of the limited time needed to get the results.

The study has set an example in the rail community which inspired two completely different rail simulation projects using the same methodology as described in this paper. In the first project a template is developed for the analysis of rail distribution networks (NS Cargo), the other project focuses on the quality of new country-wide time tables and aims to let the supporting template have a direct interface to an infrastructure and time table database (Railned - Basis, the database mentioned is called DONS). Outside the rail community the same methodology is already successfully used in shipping logistics (Bouwman, Taeymans 1997).

These results strengthen the believe of the authors that the methodology described can be successfully applied on many different application areas.

### ACKNOWLEDGMENTS

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