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SIMULATION BACKBONE FOR GAMING SIMULATION IN RAILWAYS: A CASE STUDY

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ABSTRACT

The Dutch railway is one of the world's busiest. Innovative measures are necessary, to cope with the projected growth of transport demand. The impact of innovations brings uncertainty to the decision makers and experts involved. To reduce this uncertainty, ProRail, the Dutch rail infrastructure manager, has introduced a combined gaming and simulating approach, called the Railway Gaming Suite. The development started by coupling existing simulators using High Level Architecture. It should lead to a flexible and scalable backbone to support the gaming and simulation approach. This way, the traditional application field of the simulators is extended from supporting capacity analysis, timetable robustness and construction to supporting decision making and enhancing insight in the operations. The current Railway Gaming Suite consists of three simulators. The aim of this paper is to give an overview of the approach and the underlying toolbox, applied to the concrete case: the Den Bosch station reconstruction.

1 INTRODUCTION

The railway network in the Netherlands is reaching its maximum utilization given the current infrastructure and process design. There is an ambition to have 50% more trains on the network in 2020. At the same time, lifecycle costs will have to decrease by 20%. Therefore, the challenge is to handle future growth, both in number of passengers as well as in tons of freight, against reasonable costs. ProRail is searching for solutions to use the network optimally. Traditional measures have been utilized already and now innovative approaches are needed. The urge to change is emphasized by a number of incidents that immobilized the public train services for several days last year. Those caused a radical shift of focus towards improving the robustness and the safety of the railway system.

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ProRail has three main responsibilities. The first one is to maintain the railway infrastructure and to build new tracks and stations. Secondly, there is the responsibility to handle the train traffic in a safe way. Lastly, ProRail has the responsibility to allocate capacity to train operating companies in a neutral way. In the forthcoming years, timetable planners who are handling the capacity allocation process will have to deal with capacity restrictions on some important nodes in the network. The traffic control department will have to face the difficult task to achieve a high punctuality and safety given the scarce capacity resources.

One of the nodes being adapted for the future traffic demand is the station of Den Bosch in the southern part of the country. Due to construction activities, there will be limitations in the number of available tracks in 2012 and 2013. ProRail is searching for measures to maintain the quality of the timetable and to guard the safety of passengers. The quest is to find the set of constraints that allow train traffic controllers to stay in control of the traffic flow. One of the methods used in this quest is a combination of simulation and gaming experiments. ProRail and Delft University of Technology (TUD) cooperate to develop the Railway Gaming Suite (RGS). In RGS, operational rules and decision support tools can be evaluated before being implemented in daily operations. The Suite uses existing simulation tools in a flexible and scalable context. It adds interactive functionality to enable train traffic controllers to evaluate the planning and to test new dispatching strategies. The players perform actions as in real life, where the simulators replace reality. The simulators in the Railway Gaming Suite together form a distributed simulation which is based on the so-called High Level Architecture (HLA).

The next section describes the research questions and underlying company goals, followed by the research approach in Section 4. Section 5 gives an overview of the Railway Gaming Suite and the simulators that will be used in the case of station Den Bosch. The paper ends with a look on future developments and extensions of the Railway Gaming Suite.

2 PROBLEM DESCRIPTION

Dutch railways need innovations, yet this is very complex to achieve. The 1995 politically instigated debundling of rail infra management (ProRail) and train services (predominantly NS (Nederlandse Spoorwegen), some smaller regional lines by Syntus, Arriva, Veolia, a.o., and freight transporters) has created an operational process in which multiple offices and platform/line operations need to synchronize in order to control the daily train flow. The increasing importance of rail services for individual provinces in the Netherlands has led to multi-party tendering. In this complex multi-actor and multi-level environment, the strategic safeguarding of public values in managing operations proofs often impossible (Steenhuisen et al. 2009). The combination of these events and trends brings up a challenge to innovate on two aspects, being quality in operations and increase of network capacity. The impact and benefits of proposed innovations are often questioned. It is not easy to convince decision makers and experts of their potential benefits. The need for clear insight and support on the right expert and management level arises.

2.1 Quality in Operations – Robustness and Resilience

Over the past decade, the railways in The Netherlands have received major criticism for the quality of its operations. From a policy perspective, this has led to performance contracts for both the main train service operator (NS) and the publicly owned infrastructure manager ProRail. Since then, the performance has seen improvements on the critical performance indicators, though it still is not regarded as a high quality service due to many small delays, overly crowded trains and non- or mal-informed passengers. The rail system often suffers from small defect that lead to bigger delays when the problems spread like an oil spill over the regions and lines. If we define robustness as the degree to which a system is capable to withstand problems within the limits of the designed system, then the robustness of the railways is questionable.

A lower score on robustness would not have been so detrimental if the railways were more resilient. Hollnagel et al. (2006) define resilience as the ability of a system or an organization to react to and recover from disturbances at an early stage, with minimal effect on the dynamic stability. The challenges for system safety originate from instability, and resilience engineering is a combination of methods and principles that prevent unsafe systems. Furthermore the recent years have shown that snow, storms, national festivities and other outliers in the situation for which the system is not specifically designed cause a total or at best a partial collapse of the national system, as soon as small problems begin to occur. This has led to Parliamentary Investigation (Rekenkamer 2011). According to Hale and Heijer (2006), railways, from their assessment of safety operations at the Dutch Railways, would seem to be examples of poor, or mixed resilience. They can however still achieve high levels of safety, at least in certain areas of their operations. Safety is achieved by sacrificing other goals, like traffic volume and punctuality. The system does not achieve all its goals simultaneously and flexibly and is therefore not resilient.

2.2 Capacity Increases

The Dutch railway sector formulated an ambitious program to face a massive growth of transport demand in the forthcoming decade. It is called 'Space on the Railways" ('Ruimte op de Rails', in Dutch) and it is aiming towards an increase in the number of trains on the network by 50% in the year 2020 or earlier where possible. This growth is expected in both passenger and freight transport. Currently, the Dutch railway is already approaching its maximum capacity given the current infrastructure and control mechanisms. The projected increase in transport demand requires a step-change in both the physical and the control aspects of the railways. One of the major components of this program is to switch to a timetable with high-frequency passenger trains on the major corridors. Currently there are (on average) 4 intercity, 2 to 4 local and 1 or 2 freight trains passing the major corridors every hour. This should increase to 6 intercity, 6 local and 2 freight trains. This new frequency of trains is often called 'un-timetabled travelling', as the passenger is able to go to a station without checking departure times: the next train will be there soon. The official title of the schedule is High Frequency Train Transport ('Programma Hoogfrequent Spoor' in Dutch).

The increase of capacity cannot be achieved by building new infrastructure alone: the costs for the complete program would be around 9 billion Euro and the time for procedures and construction would frustrate the transport demand for years. ProRail has taken up the challenge to achieve the goals with only half of this budget by combining strategic choices for new infrastructure with new control and management solutions.

2.3 Decision Support and Insight

As in any specialized company, the ProRail staff is full of ideas on how to improve the robustness, resilience and capacity. The innovation in the railway sector is however hindered by a lack of insight in the system-level consequences of these new ideas in the practice of the operation. Experimenting with the live traffic flow is rarely an option, especially when IT and system-wide changes are discussed. Therefore, the decision makers are uncertain about the potential effects on the system's performance. Experts and operators are uncertain about the impact on their operational tasks. Both need more insight in potential benefits and feasibility of not only the proposed innovations, but also of the current situation. ProRail introduced gaming simulation as a method to reduce the uncertainty, in cooperation with Delft University of Technology (Meijer 2012). This method is supported by a number of tools that together form the Railway Gaming Suite. The idea is to experiment with lifelike operations by simulation and to add interactivity, also called 'human-in-the-loop'. The operational crew can test new control strategies accompanied by adaptations in the man machine interface (MMI). More accurate information about train position, train speed and passenger flows may help to improve upon punctuality and robustness. ProRail already owns a number of simulation models for simulation studies. The idea is to combine these existing tools instead of rebuilding them. When needed, new simulators and interfaces may be added to explore performance and operational challenges.

3 APPROACH

The support of operational railway innovations requires a combined gaming and computer simulation approach (Meijer 2012). Computer simulation supports the modeling of real life processes like running trains, setting routes, distributing disturbances and visualizing the status of objects like trains, tracks and passengers, as well as calculation of performance indicators amongst other quantitative aspects. Gaming simulation supports the evaluation of operational rules and dispatching tasks and it gives insight in the combined socio-technical behavior of the system to all people involved.

3.1 Why Computer Simulation

Simulation methods support a number of design processes. The aim of a simulation analysis is often decision support by providing quantitative insight in complex problems. The definition of simulation knows many interpretations. Application varies from analysis of railway traffic processes, to maintenance regimes, via passenger flows and physical processes like material wear and tear. The following three examples illustrate this. Train behavior is simulated in tools that calculate or generate timetables. The calculation of train running times is an example of a static, discrete and deterministic problem. Testing the sensitivity for disturbances is a dynamic, discrete and stochastic problem. In additiona to train behavior, now train traffic control has to be modeled too. These simulation experiments consist of multiple runs due to the stochastic character. A third example is the analysis of pedestrian flows. This may be modeled as a dynamic, continuous and deterministic problem. Table 1 shows a framework to distinguish several simulation models.

Table 1: Modeling framework

Property		**Property**	
Static	No interaction between objects	Dynamic	Objects have relations and influence other objects
Discrete	Simulation of individual units or objects	Continuous	Simulation of flows
Deterministic	Precise calculations	Stochastic	Probability distributions influence calculated results
Batch	No human action needed to proceed	Interactive	Human input required during simulation

Firstly, the Den Bosch case needs a simulation environment that visualizes the train traffic flow and shows the use of the tracks and conflicting train movements. By showing a simulation (or movie) of the operational process to traffic controllers and by discussing the conflicts, they will be able to understand the impact of the proposed timetable changes. This process enables them to introduce their knowledge and give their options for better solutions. To test the ideas the simulation environment needs interactive functions where train traffic controllers may intervene the simulation run. The idea is to replace real life operation of the running of trains by the simulation. The route setting is done by the train traffic controller. By introducing human interaction during a simulation run, a fourth dimension (or interactive requirement) in the framework arises, leading to a distinction between batch and interactive simulation runs.

3.1.1 Simulation Studies in Railway Management and Operation

Like every simulation, railway simulators use a model that represents reality. Which elements should be modeled depend on the question that is to be answered. Important factors for choosing the right modeling approach and the appropriate level of detail of the data are the scale of the problem location and the core process.

The use of infrastructure in the railway sector is registered or planned in a timetable. The aim of a timetable is to plan arrivals, departures and passing events for trains at stations and nodes in the network. The timetable can be seen as a work planning for the traffic control department, a set of orders for setting the right routes for trains. At the same time, the timetable defines the travel product and offers travel times, routes and information to the customers/passengers.

The scale of a simulation study varies from a (country wide) infrastructure network on a macroscopic level to a node or a corridor configuration on a microscopic level. The macroscopic level uses nodes and links, each having a number of tracks. Conflicting train movements are constrained by headway times between train events on the stations or nodes. On the microscopic level, the layout of the railway is described by tracks and switches. The speed of a train is regulated by the signals of the safety system alongside the tracks. Here, conflicting trains are taken care of by the train control system in which routes cannot be set if part of the route is occupied or claimed by another train movement. The Den Bosch case study needs a microscopic level of detail. The controlling or dispatching rules require an accurate calculation of section occupation and route setting.

The running of a train, the core process for a railway simulation, can be described by time or by time and space. The following example illustrates the difference. In the first case, a train run between station A and B takes 10 minutes in the timetable. The first event is the departure from station A at minute 0. The second (and last) event is the arrival at station B at minute 10. The infrastructure may be on a macroscopic level. The train behavior is modeled in a simple way. In the second case the connection between A and B is modeled as a certain distance. The position of the train is calculated every time or distance step, depending on the speed instructions along the way. This model uses the train's accelerating and braking characteristics to describe the train behavior and needs a microscopic model of the infrastructure.

To efficiently produce useful results, a simulation study needs a clear approach. Close cooperation between problem owner and simulation specialist is required in the stages of problem formulation, definition of simulation experiments and choice of performance indicators, Then the modeling stage starts where representative objects from reality are chosen to be integrated in the simulation model. From this stage on, the user needs as much support as possible from the simulation tools, for instance to generate the simulation model from the companies databases and to reuse scenarios of standard simulation experiments. After validation, the model the simulation scenarios are prepared. Raw output and required reports will be produced by running the scenarios. The interpretation of the output is again a close cooperation between problem owner and simulation specialist.

3.2 Gaming Simulation for Railways

Gaming simulation, here defined as 'simulating a system through gaming methods' is one of the terms in a loosely demarcated field of interactive participatory activities, aiming to involve participants, who may be the real stakeholders in an activity. Other terms used are simulation game, policy exercise and serious gaming. The word gaming will be used here as the short term for gaming simulation. Different authors have different preferences, but generally the terms depend on the intended use of the method.

3.2.1 Application of Gaming Simulation

Given the number of gaming titles and scientific publications, the use of gaming methods for learning is the most popular by far, typically occupying 'serious gaming' and 'simulation game' for usually computer-supported games that place the player in a simulated world (Bekebrede and Mayer 2005; De Freitas and Martin 2006; Kriz and Hense 2003). Learning about innovation in games is a popular topic for MBA-style versions, typically related to markets and supply chains (Meijer et al. 2009; Meijer 2009)
In the world of policymaking, there is half a century of history in using gaming as an intervention to bring policy makers and other stakeholders in participatory events together. Games provide a way to collectively decide firstly on the system boundaries and secondly on the dynamics of the system that will be played. Then, policies can be formulated in this simulated environment (Duke 1974; Duke and Geurts 2004;

Mayer 2010). This approach relies on Duke and Geurts' (2004) 5-C's of gaming simulation for improving policy making, namely by understanding Complexity, enhancing Creativity, enabling Communication, reaching Consensus and getting Commitment to action.

Increasingly popular is the possibility of trying out the effect of policies on a simulated system, and see whether innovation in roles, rules, objectives and constraints could be made. This approach, although very relevant for policy-making, is actually a third use of gaming, for testing hypotheses (Peters et al. 1999). This application is less common and puts great emphasis on the verification and validation of the gaming simulation (Klabbers 2003, 2006; Noy et al. 2006; Meijer 2009). For innovation at ProRail, this use is at the core of the reasoning behind choosing gaming simulation as a new method in reducing uncertainty in more complex, system level changes.

A fourth use that is emerging is linked to the gamification of society (Hiltbrand and Burke 2011). Innovation can take place through game play if the incentives are such that the crowd can generate and implement their ideas in a system. Little scientific literature on this exists but examples are UK innovation in pensions (Gartner 2011) and crowd sourcing of ideas in an insurance company (Bekebrede and Meijer, Forthcoming).

3.2.2 Gaming Simulation Approach

From the launch of the initial project, ProRail formulated three preliminary cases to study using gaming simulation. TUD was asked to develop unique approaches for each of these cases, after which the initial success of gaming simulation for the Dutch Railways would be re-evaluated. The cases differed in nature. The first was about the potential value of market mechanisms for management of demand of cargo capacity. This game can be seen as a management game on the tactical level. The second case was about studying a control concept for high-frequency train transport at the Bijlmer junction. This game was at the operational level of train dispatching and network control. The third case was about the opening regimes of the bridge over the river Vecht. This game was purely about train dispatching at the operational level. During the course of these three cases, the success became very apparent to the senior management involved at ProRail. The launch of a large four-year project was marked by a kick-off case that convinced the last skeptics. All cases are described by Meijer (2012).

3.2.3 Den Bosch Case Study

The Den Bosch station is an important node in the Dutch network. Several transport flows pass through the station, thereby crossing each other. Intercity, regional and freight train services use the track layout of Den Bosch. The infrastructure configuration has no fly-over to separate crossing train movements. On both sides of the station, train services cross when heading from north to south v.v. and other services cross while going from east to west v.v.. Due to the growing number of trains there is a need to build fly-overs to separate the train services on both ends of the station. Construction works have begun last year. The available layout will change several times during the reconstruction, causing a decrease in capacity for the timetable construction and the operation. In 2013, a central section of the track layout will be out of service. To enable all train services and passenger flows required, the timetable and the platform layout will have to be adapted. Because of the size the capacity limitation, the traffic control department faces a challenge to maintain timetable quality and passenger safety. ProRail is searching for measures to help traffic controllers to stay in control of the traffic flow.

The current approach consists of three steps. The first is testing the timetable changes by simulation experiments. Outcomes of this step are insights in potential planning conflicts that might lead to delays and unsafe situations. The second step is discussing these situations with the traffic controllers and collecting their solutions by using visualization (movies and live simulation) of the train traffic and track occupation. The third step is evaluating the traffic control task in an interactive simulation. The following section gives a short overview of the relevant simulation tools that will be used in a case in the station of Den Bosch.

4 LOOKING AT THE TOOLS

Currently within ProRail, the capacity analysis, timetable construction and infrastructure design are supported by a set of advanced assignment, routing and simulation models. The simulation models evaluate timetable, infrastructure and traffic control variants on the sensitivity for disturbances on distinctive levels. Bottlenecks in the network may be found and analyzed on a local and more detailed level to find appropriate solutions. ProRail has developed three simulation models for these purposes, based on a general simulation software package (Enterprise Dynamics). One of those models (FRISO) is key for the Railway Gaming Suite, the other ones will become part of the Suite in the forthcoming years. The simulators in the Railway Gaming Suite together form a distributed simulation environment that is based on the so-called High Level Architecture (HLA). In the current version, RGS consists of:

- FRISO, a simulator that uses a microscopic infrastructure model and handles areas like corridors and nodes
- TMS, a traffic optimization simulator that is able to determine conflicts, to reschedule the train movements and to calculate advisory speeds for increasing punctuality and safety and reducing energy consumption
- PRLGame, a man machine interface for train traffic controllers

These tools are described below, future extensions of the RGS are described in Section 7.

4.1 FRISO

FRISO stands for Flexible Rail Infrastructure Simulation of Operations. It is a simulator that enables the user to perform simulation studies for problems that have dynamic, discrete and either deterministic or stochastic characteristics. Given a specific timetable, railway infrastructure, rolling stock and optional disturbances, FRISO simulates the behavior of trains and their mutual interactions It's main purpose is assessing the robustness of timetables and detecting bottlenecks. FRISO consists of railway modules that describe concepts and functions representing railway practices. The modules are shown in Figure 1.

In the simulation, trains are running along the tracks, and accelerate and decelerate when speed limits are changing. The operation of the timetable may be disturbed by delaying the departure of trains, extending dwell times with an extra delay and by varying acceleration and deceleration parameters. The internal train control module handles requesting and (phased) setting of routes.

After or during a simulation experiment, statistical and graphical results such as time-distance diagrams, histograms of arrival delays and train punctuality and animation of the processes can be viewed. FRISOs main results are running times, delay performance, headway times and occupation rates for infrastructure elements. These results generate insight in the quality and performance of the system.

A key feature of the tool is its flexibility. This is reflected in the user friendliness and the scalability of the concepts. FRISO is based on a standard simulation platform called Enterprise Dynamics, which is widely used in a variety of industries. Simulation models are generated automatically from the Infra Atlas database that holds the digital representation of the current Dutch railway infrastructure. This, in combination with smart editors for making timetable and infrastructure variants, reduces the time efforts significantly for implementing a simulation study. It allows users to spend most of their time on defining simulation experiments and analyzing the results rather than building (often manually) and validating simulation models.

FRISO has the possibility to connect to other/external applications that may take over parts of its functionality. The current version has connections to the Traffic Management System (TMS) described in the next section and to a dispatching module that allows traffic controllers to interact with the simulation model. It provides a man machine interface for route setting tasks with a similar appearance (look and feel) as the systems used in daily operation. Both modules are shown in Figure 1.

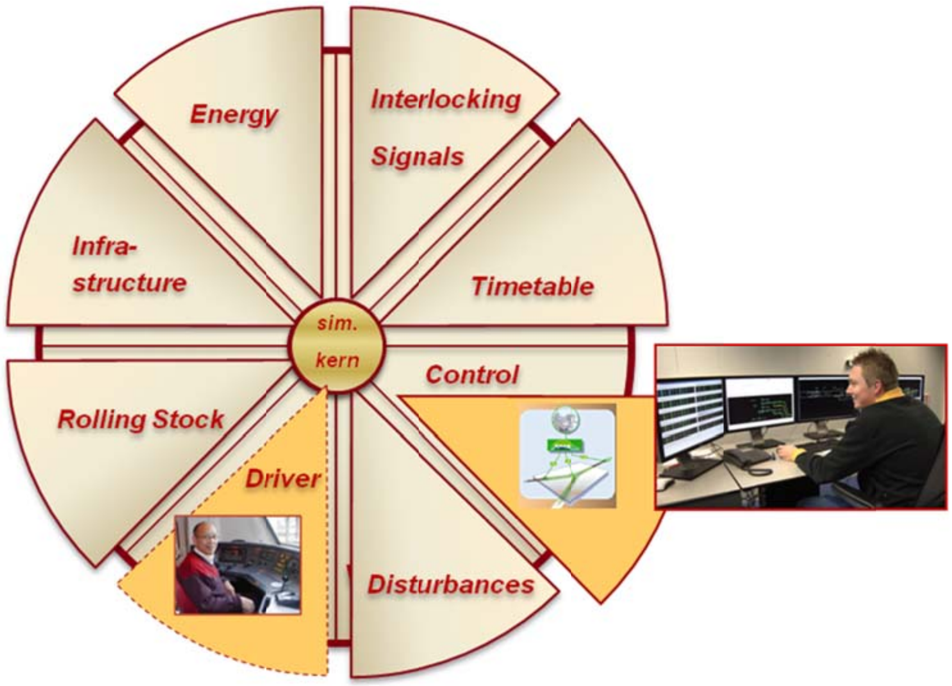

Figure 1: Modeling elements FRISO.

4.2 TMS

TMS is a Traffic Management System that controls an area in the railway network. The TMS aim is to improve the utilization of the available resources and the punctuality of trains. TMS is accurately monitoring the current train dynamics and network operating conditions. The system predicts potential conflicts and reschedules trains in real-time. For each train, the actual position, schedule, status and goals to be reached are known and frequently updated. TMS will suggest optimizations by calculating new advisory speeds for each train, changing time goals, using alternative routes and modifying train ordering at junctions. Solutions are calculated through considering the global impact on the chosen traffic performance indexes (delay, tardiness, punctuality, etc.). TMS is also responsible for the booking of a route , by an optimal choice of booking times. The potential benefits of TMS were recently shown in a simulation study in the Den Bosch area (De Vries and Lodder 2011).

The real-time scheduling engine of TMS is based on the alternative graph model (Mazzarello and Ottaviani 2008). The alternative graph is a powerful model, suitable for several real-world problems. It is fast and detailed at the same time and able to include all the relevant features and constraints in the optimization model that are necessary to produce efficient and realistic scheduling solutions. Recently, a new optimization scheme that now can use alternative routes has been developed and integrated in the graph model. Alternative routes improve the flexibility of TMS when it is looking for solutions to prevent heavy conflicts or trying to avoid traffic congestion. On the other side, alternative routes increase the complexity of the optimization problem and the explosion of possible combined alternatives can pose serious computational problems, which may conflict with real time constraints.

4.3 PRL GAME

PRL stands for Process Control (‘Procesleiding’ in Dutch). This is the control system for train traffic controllers. It consists of screens showing the infrastructure layout of a control area and the routes that have been set and are in use by trains. The timetable is shown as a Time-Distance graph and as a set of process rules. The train traffic controller is also supported by an automated route setting module (ARI).

Via the man machine interface (MMI) the traffic controller monitors the train traffic and changes requested routes when necessary. For maintenance or incident reasons he takes infrastructure elements out of service or blocks them to prevent accidents. In the Railway Gaming Suite a real life resembling MMI has been built and connected to a FRISO simulation model, see Figure 1. By this combination the simulation gets an interactive character and becomes suited for games that investigate the traffic control task under changing circumstances.

5 RAILWAY GAMING SUITE – THE COMBINATION OF MODULES

In order to enable the use of the existing simulators within the Railway Gaming Suite there should be a solid backbone, an appropriate architecture that supports flexible and scalable mutual dynamic connections. Verbraeck et al. (2011) compared four options for coupling simulators in a study evaluating on a long set of criteria and subjecting the options to extensive performance testing. The options were:

- SOA – Server Oriented Architecture,
- FAMAS – A light-weight coupling solution,
- RTI-DDS – A publish-subscribe mechanism, and
- HLA – High Level Architecture (IEEE 1516-2000 standard). ProRail used an earlier version of this IEEE standard to connect FRISO and TMS and to interconnect modules in BITS.

The RGS team has chosen HLA to build a backbone for the simulation and gaming experiments. The HLA standard specifies interfaces between components and defines the steps for the development and execution of a simulation scenario. HLA contains synchronization mechanisms that allow consistent time management and interaction between the simulators and other applications. The applications in such a scenario are also known as federates. Together they form a federation and have to cooperate, communicate and synchronize mutual information.

The criteria used were consistency/causality, consistency/multiple time paradigms, consistency/semantic and pragmatic interoperability, failure detection, fault tolerance, error recovery, maintainability, fast session setup, centralized facilitator access, component extensibility and ontology extensibility (Verbraeck et al. 2011). However, coming to this coupling, especially in a brown-field situation is far from trivial. Since 2011 there is a development team that has started the development of the HLA federation, following the DSEEP, Distributed Simulation Engineering end Execution Process (IEEE Std 1730-2010). Based on a new Federate Object Model (FOM), existing and new simulators are integrated in RGS.

The process in itself is subject of research, because of the new frontiers faced. There are few best practice examples of non-military simulators using HLA. There are also only a few experiences described that expand existing HLA connections like the BITS and FRISO-TMS federation to a multi HLA environment. Aside from technical problems, documentation and conflicting interests (or goals) of departments play a role. Support in the organization is maintained through a shared future vision, described in Figure 2, in which the coupling of multiple simulators, but also the possibility to take over simulated roles with gaming modules is depicted.

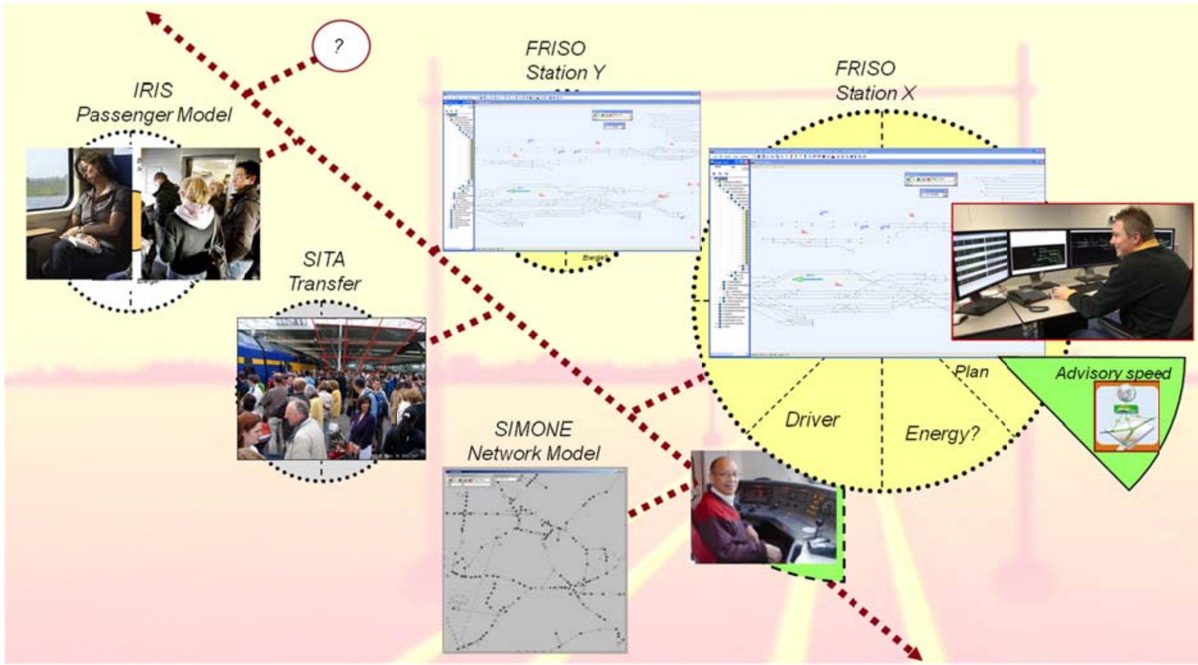

Figure 2: Railway Gaming Suite with HLA-backbone.

5.1 Existing HLA Federation FRISO-TMS

FRISO and TMS were originally developed as standalone applications. An earlier pilot in which TMS was connected to real life trains showed promising results. Further development took place by connecting it to FRISO to investigate potential future use. TMS must be able to take over internal FRISO train dispatching tasks and exchange information on the actual position and status of the trains. During a simulation, FRISO informs TMS about location and status of the trains, the occupation of the infrastructure, allowed speed profiles restricted by the signaling system and the allocation of routes. TMS returns advisory speeds, booking of routes and (later also) change of track allocation. To guarantee re-usability and interoperability the High Level Architecture standard (IEEE, 2010) has been chosen.

Mappers are used to translate messages of FRISO and TMS to HLA. These are connected to the so-called Run Time Infrastructure (RTI) based on HLA principles. The RTI takes care of time synchronization, saving and restoring simulations and updating information and enables the federation for execution. By using the mappers and HLA, it has become relatively easy to replace TMS with another traffic management system or to replace FRISO with another railway simulator.

6 FUTURE DEVELOPMENTS

The toolbox is growing, but coupling the components is far from trivial. Therefore low-tech gaming is still being used. First results with FRISO-PRL are quite promising, so the 'threshold' of performing an HLA-process is justified. ProRail already notices more success in implementing innovations with this early RGS-version.

In the near future, the existing Railway Gaming Suite will be extended with more functionality. Several ideas like bringing new information (TMS-solutions for conflicting trains, accurate train status information, network delay propagation or passenger flow information) to the traffic controllers, the network controllers and the train drivers or the integration of train traffic and passenger flows, may help to come to better performance. Candidate tools for these functions are shown in Table 2.

Table 2: Simulators/federates in the Railway Gaming Suite.

FRISO	Microscopic infrastructure	Train behavior, infrastructure occupation, traffic control
TMS	Microscopic infrastructure	Optimization of train traffic
PRL-Game	Schematic infrastructure	Man machine interface
3D train driver	3D model infrastructure images	Man machine interface
SIMONE	Macroscopic infrastructure, network level	Train behavior, infrastructure occupation, traffic control
BITS	Microscopic infrastructure	Infrastructure occupation, safety sytem emulation
IRIS	Macroscopic infrastructure	Passenger and train delays
SITA	Transfer infrastructure	Pedestrian flows

To monitor the influence of the combined simulation and gaming approach and the tools in RGS, a longitudinal research project has been started. This will follow the decision making in the innovation processes of ProRail for 4 years.

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