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Introducing gaming simulation in the Dutch railways

Sebastiaan Meijer*

KTH Royal Institute of Technology, Stockholm, Sweden; Delft University of Technology, The Netherlands

Abstract

Innovation in the Dutch railways in the domain of capacity management and traffic control is increasingly difficult to implement because of the large interconnectedness of all processes and separation into different institutions and organizations. Meanwhile there is a push for quality improvements leading to more robustness and resilience as well as a significant capacity increase. In the years 2009 - 2010, the gaming group of Delft University of Technology was asked to introduce gaming simulation methodology at ProRail, the Netherlands' rail infrastructure manager, to support innovation projects. Three initial trial projects ran so successful that the organization asked the Delft researchers to identify where in the organization large-scale implementation of gaming simulation methodology would be most promising. Based upon a series of interviews through the organization, ProRail and TU Delft jointly formulated a four-year research and implementation proposal that is now in operation. The first gaming session in this new collaboration proved the essence of the fit of gaming simulation for innovation at the Dutch railways. Unique for gaming simulation is the highly detailed simulation of both the more technical and process variables of rail infrastructures as the decision and communication function of real people in their real roles. The method does not assume models of decision-making but draws upon the real-world knowledge of professionals in the operation. The paper gives lessons learned on methodological challenges resulting from the four projects described.

Keywords: gaming simulation; innovation; railway operation; infrastructure management

1. Introduction

The Dutch railway system is a highly complex and heavily utilized network (Goverde, 2005; CBS, 2008). Improvements in the domain of capacity management and traffic control are increasingly difficult to implement because of the large interconnectedness of all processes. Because of a 50% growth challenge till the year 2020, new and smarter ways of managing capacity and traffic are key for the

* Corresponding author. Tel.: +46734619820; fax: +31152786233.
E-mail address: smeijer@kth.se

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success of the Dutch rail infrastructure for society. The ProRail organization looks into gaming simulation as a key method to improve the innovation process.

In the years 2009, the gaming group of Delft University of Technology was asked to facilitate three projects using gaming simulation methodology. These projects ran so successful that the organization asked the Delft researchers to identify where in the organization large-scale implementation of gaming simulation methodology would be most promising. Based upon a series of interviews through the organization, ProRail and TU Delft jointly formulated a four-year research and implementation proposal that is now in operation. The first gaming sessions in this new collaboration have been held and results are coming in. It was the first gaming simulation that really made the big jump in acceptance in the organization.

Unique for gaming simulation is the highly detailed simulation of both technical and process variables of rail infrastructures and the decision and communication function of real people in their real roles. The method does not assume models of decision-making but draws upon the real-world knowledge of professionals in the operation.

2. Problem description

Innovation in the Dutch railways is on one hand much needed, while on the other hand very complex to achieve. The 1995 politically instigated de-bundling of rail infra management (ProRail) and train services (predominantly NS, and some smaller regional lines by Syntus, Veolia, a.o.) has created an operational process in which multiple offices and platform/line operations need to synchronize to control the daily train flow. The increasing importance of rail services for individual provinces in the Netherlands has led to multi-party tendering (Van de Velde *et al*, 2008). 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 leads to a challenge to innovate on two aspects, being quality in operations and ways to increase the capacity.

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 (Van de Velde *et al*, 2009). Over the past decade the performance has seen improvements on the critical performance indicators, but still it 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 defects, leading 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 to system safety come from instability, and resilience engineering is an expression of the methods and principles that prevent this from taking place. 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 total or at best partial collapse of the national system, as soon as small problems start 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 at best mixed, resilience, which can, however, still achieve high levels of safety, at least in certain areas of their operations. Hence safety is achieved by sacrificing goals, traffic volume and punctuality. The system does not achieve all its goals simultaneously and flexibly and is not resilient.

2.2. Capacity increases

The Dutch railway sector will face a massive growth of transport demand in the forthcoming decade. This growth is both expected in passenger and in freight transport. Currently, the Dutch railway network is one of the most densely used networks in the world, approaching its maximum capacity given the current infrastructure and control mechanisms. The projected increase in demand requires a step-change in both the physical and control aspects of the railways. ProRail formulated an ambitious program, called 'Room on the Railways" (Ruimte op de Rails, in Dutch) to increase the number of trains on the network by 50% before the year 2020. One of the major components of this program is the plan for 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 per hour on the major corridors. This should increase to 6 intercity, 6 local and 2 freight trains before 2013. This new frequency of trains is often called 'untimetabled travelling" as the passenger can just 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.

The projected 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.

3. Gaming simulation for process innovation

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. 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 together policy makers and other stakeholders in participatory events. 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 the Complexity, enhancing Creativity, enabling Communication, reaching Consensus and Commitment to action.

Increasingly popular is the possibility to try out the effect of policies on a simulated system, and see whether innovation in roles, rules, objectives and constraints can 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. Few scientific literature on this exists as of yet, but examples are UK innovation in pensions (Gartner, 2011), crowd sourcing of ideas in an insurance company (Bekebrede and Meijer, Forthcoming)

4. Convincement through 4 cases

From the launch of the initial project, ProRail formulated three preliminary cases to study using gaming simulation. TU Delft was to developed 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 could 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. This led to an Intermezzo phase after the third game to reflect upon the results so far and to identify the value from interviews with ProRail internal stakeholder held by Delft researchers. The launch of a large four-year project was marked by a kick-off case that convinced the last skeptics. In the following sub-sections each of the cases and the intermezzo phase are described.

4.1. Rail Cargo Market Game

The first and kick-off subproject called Goederenmarktplaats (Freight Market) introduced ProRail to a paper-based and partly computer-supported game with a high degree of abstraction. This game type was referred to as a management game, due to the focus on more abstract policy-related aspects. Most of the participants were managers, with one session including a small number of network controllers.

Table 1 lists the core description of this game, more information can be found in Meijer *et al* (2009).

Table 1: Core description of Rail Cargo Market Game

Core aspect	Description
Purpose	Studying the potential value of various market mechanisms for better capacity allocation of cargo paths.
Roles	Clients with demand for transport, Rail Cargo Transporters, Passenger Transport, Rail Capacity Planning, Rail Asset Management
# of players	15 – 25 depending on step
Own/real/fictitious role	Real role, but selected for knowledge for instance from previous job position.
Scenarios	3 – 4 scenarios per session. First scenarios that explored the more fundamental market mechanisms. Then scenarios to

	validate the successful configurations.
Intervention range	Facilitator could start and stop the scenario and dissolve disputes only on the process steps.
Simulated world	Stylized train path market, stylized transport demand
Round-based/continuous	Continuous
# of sessions	3 subsequent games each with 1 session during 1 full day.
Type of data generated	Quantitative and qualitative, testing hypotheses about mechanisms that are assumed to have a certain effect on capacity allocation.
Consequences	Policy formulated but put out of scope for 2010/2011, possible application in 2012. Politically very sensitive.

The game sessions delivered results timely, and in a positive and active manner. This game is still referred to two years later in the organization. Important to note for the introduction of gaming is that this project happened to have many people on board in senior staff functions from two different divisions (Traffic Control and Capacity Management) who appeared to be key people in later problems that called for gaming simulation methodology. The foundation in terms of exposure to key personnel therefore couldn't be better.

4.2. Bijlmer Junction Game

This subproject introduced ProRail to a computer-based gaming simulation developed on ProRail's own MATRICS simulator (Van Luipen and Meijer, 2009). This simulation pushed the envelope in terms of utilizing the technical specifications of MATRICS. This type of game was described as a multi-player process simulation due to its detailed reflection of real-life operational processes. The participants play a pre-defined role that is 100% identical to their job description, to carry out their real-life duties in a simulated game environment. Table 2 lists the core description of this game. For a full description we refer to Meijer *et al* (2009).

ProRail had assigned a project team to come to new control and steering procedures that suite the future reality of high-frequency passenger trains. The challenge of this project team was to come up with new concepts that would both be supported by train traffic controllers and network controllers, and would yield a stable, controllable control and routing operation when put into place. The question was raised: how to test new control and steering concepts when there is no option to test in real life? The Bijlmer Junction Game was targeted at this. In the game the interaction of train drivers, traffic controllers and network controllers was crucial, as studied earlier by Albrecht (2009).

Table 2: Core description of Bijlmer Junction Game

Core aspect	Description
Purpose	Testing and validating a control concept for high frequency train transport.
Roles	Train driver (2), Train traffic controller (3), Network controller (5)
# of players	10 plus 2 facilitators and 2 experts.
Own/real/fictitious role	Own role, participant selected by their team leaders
Scenarios	3 Scenarios, gradually testing more complexity.
Intervention range	Facilitators could start, stop and pause scenarios and

	interfere with train driver behavior.
Simulated world	Detailed infrastructure between Amsterdam and Utrecht, detailed timetable.
Round-based/continuous	Continuous
# of sessions	1 full day session
Type of data generated	Quantitative (failed) and qualitative.
Consequences	Data generated in the game yielded insights in key materials and resources needed for implementation of the control concept, and high-frequency planning in general.

The gaming simulation session yielded insights in key materials and resources needed for implementation of the control concept, and high-frequency planning in general. The importance of buffer areas with sufficient space to side-track a train without disturbing other services, platforms asides the entire train for passenger exit, and alternative departure options for all passengers within reasonable time is a clear outcome for ProRail. Furthermore, train traffic controllers do not yet seem to realize what the projected high-frequency planning will mean in practice for their tracks.

As described in Meijer *et al* (2009), this game was not a break-through success. We learned that involving the operational people in the organization in a game that modeled the infrastructure and timetabling as detailed as they are used to, requires interfaces that connect to the situation awareness capabilities of these operators. Simple said: even though we checked our approach upfront with the operators, they were not able to do what they though were capable of due to different visualization. Luckily, the debriefing and discussions still yielded sufficient data of sufficient quality for ProRail to be able to contribute to the problem solving. For the gaming team, this experience led to the development of the following game.

4.3. Railway Bridge Game

The subproject Railway Bridge Game (for a bridge over the river Vecht) introduced ProRail to the process management game, a computer-based gaming simulation for which new software was developed. Over the course of one week, various train traffic controllers played this game in a single-player environment using a series of scenarios. The type of game was described as a single-player process simulation. Table 3 gives the core description of this game. More information can be found in Kortmann and Sehic (2010).

Table 3: Core description of Railway Bridge Game

Core aspect	Description
Purpose	Studying a new regime for bridge openings on the busy Amsterdam – Amersfoort corridor.
Roles	Train traffic controller. Bridge operator (simulated)
# of players	1
Own/real/fictitious role	Own role.
Scenarios	5, each subsequent day the same train traffic controllers played one scenario of increasing complexity
Intervention range	Facilitator played other roles
Simulated world	Detailed infrastructure, detailed time table

Round-based/continuous	Continuous
# of sessions	1 session, full week
Type of data generated	Mainly quantitative (measured actions and train throughput, questionnaires) and qualitative from interviews
Consequences	None as of 2011, new game with improved interfacing planned for winter 2012 testing more details.

The Railway Bridge Game was positively received. It learned that the drawbacks of the interface problem signaled in the Bijlmer Junction Game could be overcome by making special gaming modules. Now the question is how to proceed with these modules. This is discussed in Section 5.2.

4.4. Intermezzo: results of 1st phase

So far, the 2008-2010 pilot project covered three subprojects that used gaming-simulation to investigate various solution strategies and innovation projects with the aim of increasing capacity utilization on the rail network.

The research team then conducted interviews within ProRail to evaluate the pilot project and identify the opportunities it presented. In these interviews, the management game was repeatedly described positively. However, this generated few new ideas as regards applicability. Many of the issues encountered within the ProRail organization are operational and thus call for less abstract forms of gaming simulation.

Both single-player and multi-player gaming simulation were readily welcomed by almost all of the interviewees as a valuable new resource for ProRail as an organization. The aspect of the multi-player gaming simulation that prompted a particularly positive response was the opportunity to test the feasibility of timetables, control concepts and exceptional situations in a setting that includes several layers of management and/or control areas. The aspect of the single-player gaming simulation that prompted a particularly positive response was the opportunity to train and practice in relation to exceptional situations and future timetables and infrastructures in an offline setting, using simulated trains.

An important aspect of both the multi-player and single-player gaming simulation is the opportunity to communicate ideas. While a slideshow can communicate a message, a gaming simulation enables you to experience it for yourself. The aspects about which it is sometimes difficult to communicate at present include: the impact of new timetables (on all categories of employees), the need for precision in carrying out tasks (employees), the influence of disruptions on the network as a whole (general public) and to experience the key aspects of Traffic Control / Capacity Management (general public). At present, visualizations of train flow models such as FRISO and SIMONE (Middelkoop and Loeve, 2006) are available, but it is not possible to experience these aspects by sitting at the controls. The opportunity for communication gives employees the chance to play a role that they do not have in reality. This can help clarify different points of view.

The interviews allowed us to arrive at a framework for the first phase of a prospective railway gaming suite. The Further Research-section presents the range of possibilities that lead to a gaming suite with multi-player and single-player gaming simulations. For the process of introducing gaming simulation it is important to note that once the contract was signed the urge to get a really good starter became more and more prominent. The following case was a make-or-break case, given the strategic position of the project.

4.5. ETMET 2010

One of the two strategic innovation trajectories to come to the desired capacity increase is the program to come to a metro-like timetable on the major corridors. On the Amsterdam – Eindhoven corridor this program is titled 'Every Ten Minutes A Train' (Elke Tien Minuten Een Trein – in Dutch), shortly ETMET. In the fall of 2010, the largest train operator National Railways (NS) and ProRail tested this concept for a full month in the real operation. This program required substantial preparation, and gaming simulation was selected through the senior staff involved in earlier games to answer questions about two ways of handling a major disruption under the new timetable. This resulted in the ETMET 2010 Game, described in Table 4.

Table 4: Core description of ETMET 2010 Game

Core aspect	Description
Purpose	Testing the differences between two mechanisms of handling a major disruption under High Frequency Transport scheduling
Roles	Train traffic controllers, Passenger information, Driver rescheduling, Rolling Stock rescheduling, Platform coordinator, Network controller, Service controller.
# of players	14 in role, 9 in support roles in analog simulator center, 6 observers, 1 host, 1 game leader
Own/real/fictitious role	Own roles, invited on personal title however with support of management.
Scenarios	2 scenarios: first the 'old' way and then a new mechanism
Intervention range	Facilitators could start, stop and pause the scenarios.
Simulated world	Detailed infrastructure Utrecht - Geldermalsen, detailed high-frequency timetabling, essentials of communication lines between different offices involved. Stylized passenger flow.
Round-based/continuous	Continuous
# of sessions	1 session, full day
Type of data generated	Quantitative and qualitative, testing hypotheses about differences between 2 mechanisms.
Consequences	Proposed solution abandoned based on data generated in the gaming session.

In the ETMET 2010 Game we simulated the train flow and all processes and interactions in the train control, personnel and rolling stock processes. The wish was to have the train traffic controllers working on gaming modules similar to the one in the Railway Bridge Game. Soon during the development we found out that the underlying rail traffic simulators available did not support the required actions of turning around, skipping a service or renumbering rolling stock to different train services. Therefore the decision was made to create a complete manual, analog simulator, observed with cameras overhead the infrastructure maps, distributing views similar to the regular computer visualizations to three rooms with operators.

The session delivered the data required to answer the question on the differences between two methods of handling a major disruption. The project management assumed the new method to be beneficial for resilience, however they proved wrong. During the gaming session all senior management of ProRail and NS involved came by and stated their impression with the integrative and concerted way of simulating organizationally heavily separated offices and processes. The case proved to live up to the high expectations surrounding the project, thus safeguarding the kick-off.

5. Methodological challenges

The experiences with the games mentioned above have confronted the research team with a series of methodological challenges. We frame these challenges as a result of the first phase as they could appear from gaining experience with the particular context actually carrying out experiments in the real organization. The challenges can be described in four categories.

5.1. Timing and role of gaming simulation

Given the positive outcomes of the projects described, gaming simulation gained an aura of a 'golden tool' for solving complex multi-layered operational issues. Time needs to be spent to identify where, what and why this method can really contribute to improve the innovation capacity of the organization. The breath of the four cases mentioned above give a first indication on the potential value for evaluating designs and testing hypotheses. The other three uses of gaming mentioned above are still open and possible as well. Comparisons with other methods to support decision-making need to be done to position gaming.

5.2. Software game modules

Overcoming interface issues and with that the cognitive capabilities for situational awareness of operators can be solved using software game modules that emulate a real workplace of for instance a train driver or train traffic controller. These modules need to interconnect with traffic simulation models, each other and infrastructure information databases. Because of the current state of accepted models and technology at ProRail, our project will integrate systems through HLA runtime infrastructures. This requires research into distributed discrete simulation and gaming, and area that so far has received little attention apart from the military. A shared Federation Object Model and data dictionary in a brown-field situation like the railways is notoriously hard and requires adaptations to the methods that exist in this field like DSEEP and FEDEP (IEEE, 2010).

5.3. Validation

The sessions usually run only once. Drawing conclusions on just one session puts emphasis on the validity of the behavior observed and decisions made in the simulation. The number of people to validate a full game with is limited in terms of availability (they work in de 24/7 operation) and costs, validation approaches need to be done differently. By modularizing the toolkit of gaming into sub-models and software components, validation of the components can be done outside of the final game sessions. Work on the validation requires deeper understanding of train traffic control and train driver behavior. This encompasses the knowledge base in the organization. Work on this gives methodological challenges that go beyond the literature on gaming methodology (Peters *et al*, 1999)

5.4. Development speed.

ProRail uses a version of PRINCE2 project management. This leads to an organization with many projects of 6 – 12 month duration. The time between the formulation of a question and the deadline for the answer is usually so short that developing special (software) tools proves impossible. Challenges are ahead (and actually experienced already) to match the demand in the organization with the supply generated in the four-year project. In innovation this is the traditional gap between creating market or demand for new tooling and the capability to deliver it. The project has to find ways to manage this.

6. Conclusions

The sequence of four gaming simulation project led to a successful introduction in the ProRail organization of the gaming method. Full support has led to a four-year partnership between academics and the operation to make gaming suited for ProRail and ProRail suited for gaming. This however proves to be far from trivial and raises four categories of methodological issues to be tackled along the project.

Once this project has been carried out, ProRail will have at its disposal a gaming suite that connects with existing rail traffic simulators. The gaming suite will make it possible to configure a game simulation session without the need to call in outside expertise by selecting timetables, locations, actors, duration and measurement variables. The gaming suite can be used for two types of applications: decision-making support (joint fact-finding) and training/education. They can also be used for a combination of the two (education and decision-making support).

For decision-making, the railways gaming suite aims to "rehearse the future" by using simulation models, information systems, analytical methods, games and other interactive techniques alongside the existing decision-making processes. The key feature is the possibility to create 'what-if' scenarios. The outcomes of these scenarios support the decision-making process by providing an understanding of the problems and the pros and cons of the possible solutions. Other applications and limitations need further exploration.

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