The Power of Sponges – High-tech versus Low-tech Gaming Simulation for the Dutch railways

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Abstract. To facilitate innovation in transport systems there is a need for simulated environments to experiment with new configurations, ideas and solutions. Gaming simulation is such an environment, and this paper presents the approach applied in capacity allocation and traffic control innovation for the Dutch railways. Both high-tech and low-tech games have been build and applied. This paper discusses the differences in use and value of the two types. Real-world application in seven cases has shown that the actual purpose of low-tech and high-tech games does not differ so much, but that the level of detail in the quantitative data yielded is much better in the high-tech games, as can be expected. Low-tech games however have shown a good purpose in questions where multiple types of roles had to be present. Connecting them to high-tech games requires other components that have long development times. Even though these modules are currently under construction, the low-tech games continue to fulfill their purpose due to their capability of stylized representation of systems and data.

Keywords. Gaming simulation, traffic control, process innovation, fidelity

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 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 2009 - 2010, 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.

Gaming simulation comes in many flavours. At ProRail the author and his team use both low-tech and high-tech gaming simulation. Unique for the approach is the focus in the 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 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).

High-tech or Low-tech?

In the field of applying gaming simulation for learning there is much attention for the value of fidelity of games for the transfer of specific skills and knowledge (Druckman, 1994; Feinstein and Cannon, 2002, a.o.). Generally, the conclusion there is that more specific skills require gaming environments of higher fidelity to good transfer. The author has shown (Meijer, 2012) that for railway gaming with the actual operators one needs high fidelity on the infrastructures, time-tabling and processes. The question remains that given the possibility to achieve the required levels of fidelity for most research questions both with low-tech and high-tech games, what type of approach is best suited to support innovation in the railway sector.

3 Railway innovation problem

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.

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.

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.

4 Seven cases, seven experiences.

In the period 2009 – 2011, ProRail and TU Delft have used gaming simulation in seven actual innovation projects, and plan to continue and intensify the use from 2012 onwards. Meijer (2012) gives an overview of the first 6 cases and detailed descriptions of the purposes and design choices. The 7th case is a replication of Case 3 (Railway Bridge Game) with improved gaming software and simulations. In the
current paper we stick to shorter descriptions, important for the consequences of high-tech versus low-tech solutions in the design of the games.

From the launch of the initial project, ProRail formulated three preliminary cases to study by using gaming simulation. 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.

Now that gaming simulation as a method was accepted, further cases were added. The fourth case handled about different ways of solving a major disruption under a 50% increased train pattern, called ETMET. Case 5 researched the consequences of new train traffic control areas based upon corridor separation, and the sixth case aimed to find the capacity constraints of overnight parking procedures due to overflowing train parking locations. The seventh case replicated the Railway Bridge Game with better simulation tools.

With regards to the technology used, we can call Cases 1, 4, 5 and 6 low-tech simulations, as they were designed as board games, using paper and pencil, visualisation with scour sponges, print outs, labels and coloured materials. Cases 2, 3 and 7 can be called high-tech simulations, as they relied on computer simulators, laptops, etc, to be able to play the game. Table 1 lists characteristics of the low-tech games, and Table 2 lists them for the high-tech cases.

### Table 1. Characteristics of low-tech cases

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Rail Cargo Market Game</th>
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<tbody>
<tr>
<td>Purpose</td>
<td>Studying the potential value of various market mechanisms for better capacity allocation of cargo paths.</td>
</tr>
<tr>
<td>Roles</td>
<td>Clients with demand for transport, Rail Cargo Transporters, Passenger Transport, Rail Capacity Planning, Rail Asset Management</td>
</tr>
<tr>
<td>Type of role</td>
<td>Real role, selected for pre-existing knowledge.</td>
</tr>
<tr>
<td>Simulated world</td>
<td>Stylized train path market, stylized transport demand</td>
</tr>
<tr>
<td>Development</td>
<td>2 months</td>
</tr>
<tr>
<td>Type of data generated</td>
<td>Quantitative and qualitative, testing hypotheses about mechanisms that are assumed to have a certain effect on capacity allocation.</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Case 4</th>
<th>ETMET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Testing the differences between two mechanisms of handling a major disruption under High Frequency Transport scheduling</td>
</tr>
<tr>
<td>Roles</td>
<td>Train traffic controllers, Passenger information, Driver rescheduling, Rolling Stock rescheduling, Platform coordinator, Network controller, Service controller.</td>
</tr>
<tr>
<td>Type of role</td>
<td>Own roles</td>
</tr>
<tr>
<td>Simulated world</td>
<td>Detailed infrastructure, high-frequency timetabling, essentials of communication lines. Stylized passenger flow.</td>
</tr>
<tr>
<td>Development</td>
<td>6 weeks</td>
</tr>
<tr>
<td>Type of data generated</td>
<td>Quantitative and qualitative, testing hypotheses about differences between 2 mechanisms.</td>
</tr>
</tbody>
</table>
Case 5  NAU

Purpose  Testing the improvements in resilience and robustness when introducing a new control concept for Utrecht Central station.

Roles  Train traffic controllers, Decentralized network controller, Driver rescheduling, Rolling Stock rescheduling, Platform coordinator, Network controller, Service controller.

Type of role  Own roles

Simulated world  Detailed infrastructure Utrecht Central, detailed current timetabling, face-to-face communication lines between different offices involved. Stylized planning tools

Development  2 weeks

Type of data generated  Quantitative and qualitative, testing hypotheses about improvements with new control concept. Numbers real enough to base decisions on.

Case 6  Platform Overnight Parking

Purpose  How many pieces of rolling stock could be parked along the platforms of stations during the night, given the processes of cleaning and maintenance that have to be performed at service areas? Question asked for two locations.

Roles  Train traffic controller, Foreman of cleaning, Train driver, Service area supervisor.

Type of role  Own roles

Simulated world  Detailed infrastructure Amsterdam Central – Amsterdam Watergraafsmeer and Hoofddorp, detailed timetabling for end-of service of trains. Detailed service demand,

Development  6 weeks

Type of data generated  Quantitative and qualitative, delivering a range of rolling stock feasible to park

Table 2. Characteristics of high-tech cases.

<table>
<thead>
<tr>
<th>Core aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Testing and validating a control concept for high frequency train transport.</td>
</tr>
<tr>
<td>Roles</td>
<td>Train driver, Train traffic controller, Network controller</td>
</tr>
<tr>
<td>Type of role</td>
<td>Own role</td>
</tr>
<tr>
<td>Simulated world</td>
<td>Detailed infrastructure between Amsterdam and Utrecht, detailed timetable.</td>
</tr>
<tr>
<td>Development</td>
<td>2.5 months re-using existing tooling</td>
</tr>
<tr>
<td>Type of data generated</td>
<td>Quantitative (failed) and qualitative.</td>
</tr>
</tbody>
</table>

Core 3 and 7  Railway Bridge Game, V1 and V2

Purpose  Studying a new regime for bridge openings on the busy Amsterdam – Amersfoort corridor.

Roles  Train traffic controller. Bridge operator (simulated)

Type of role | Own role. |
| Simulated world | Detailed infrastructure, detailed time table |
| Development | 7 months for V1 and another 18 months for V2 |
| Type of data generated | Mainly quantitative (measured actions and train throughput, questionnaires) and qualitative from interviews |
5. Low-tech versus High-tech

When we compare the Table 1 and Table 2 there are a few trends that emerge from the three years collaboration project. This section identifies and discusses them.

Purpose

If we look at the purposes of the gaming sessions one can see that all have been used to test or validate ideas, design and scenarios together with real operators. Only Case 1 was a little exception, as the participants were ex-operators who are now in senior positions.

What is not in the Tables, but can be taken from background materials is the difference in the purpose for the innovation projects that the cases were used for. All of the low-tech cases were used to see whether a pre-designed concept was actually good when put into the operations. Project managers wanted to test their concepts, and pick-up a lot of requirements for successful implementation along the way as well. The three high-tech cases however used gaming to test a fundamental idea in a very early phase of development. The idea was given in instructions to the operators who could then do their regular job in the simulated environment. Analysis of the output data should reveal the fundamental correctness of the idea.

This observation is contradictory to what the usual flow in innovation trajectory is. Decision-making models like Stage-Gate suggest making ideas more and more specific over time but start with generic assessment of the costs and benefits. Apparently there is logic in the railway domain to test a generic idea with specific simulation.

Development time

The low-tech games have much shorter development cycles, as can be seen from Table 1 and 2. This is logical, as the high-tech ones require programming of modules that connect to rail traffic simulators. This connection is challenging, as is getting the response of the system as close as possible to the real workstations of the operators. The long development times often cause problems.

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. In innovation this is the traditional gap between creating market or demand for new tooling and the capability to deliver it. Once the software is there, it can be applied fast, but in the meantime the low-tech tools have done a better job in answering current questions.

Qualitative versus quantitative

Table 1 and 2 show that both low-tech and high-tech gaming simulations delivered quantitative and qualitative results. The high-tech cases have a little bit more emphasis on the qualitative part, while the low-tech cases put more emphasis on the qualitative aspects as well. If we look at the cases in detail we see that the type of data
is less dominant here than the type of process simulated. The questions answered in the high-tech cases have a heavy dependence on the details of railway interlocking (the safety systems).

**Detailed versus stylized simulated world.**

In Meijer (2012) the author analyzed the requirements for getting railway operators involved in their role given different questions and abstractions. 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. However, the paper also showed that the level of detail required for most questions could be reached with low-tech modelling.

Comparing the type of questions in Tables 1 and 2 shows that the aforementioned importance of process details for some questions on the railways gives the push to introduce high-tech gaming simulations. As soon as the processes involve detailed interlocking, the gaming has to move from low-tech to high-tech.

**Number of roles**

Table 1 shows clearly that so far there have been many more roles involved in the low-tech games than in the high-tech ones. This can be explained from ability of low-tech games to connect roles by giving stylized information and modelling. The more specific and detailed information is required in a process, the harder it is to connect a role using stylised models.

The logical consequence of this is a push to develop more modules for more roles that can connect to the high-tech gaming simulations for train traffic controllers. 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, the 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. **Conclusions**

Three years of collaboration between ProRail and TU Delft have yielded a toolkit of low-tech and high-tech gaming simulations. Actual applications in seven cases have shown the value of these tools, which is currently underlined due to a massive uptake in the organisation in 2012. The applications have shown that the actual purpose of low-tech and high-tech games does not differ so much, but that the level of detail in the quantitative data yielded is much better in the high-tech games, as can be expected. Low-tech games however have shown a good purpose in questions where multiple types of roles had to be present. Connecting them to high-tech games
requires other components that have long development times. Even though these modules are currently under construction, the low-tech games continue to fulfil their purpose due to their capability of stylised representation of systems and data. The forthcoming years will show what the success of high-tech games with many roles involved will be. Based on current experiences one can expect a mutual co-existence within the organisation.

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