C4R

Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Report from Virtual Demonstrations

Submission date: 23/11/2017

Deliverable 55.5

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Acronyms and Abbreviations

The following list provide definitions for acronyms and abbreviations and for terms used in this document:

CBA	Cost-Benefit Analysis
IMs	Infrastructure managers
LCC	Life-Cycle Costs
RAMS	Reliability, Availability, Maintainability and Safety
RFC	Rail Freight Corridor
GIS	Graphical Information System
WP	Work package

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Executive Summary

This deliverable explains the work carried out as part of task 5.5.5. This task had the aim to:

Demonstrate the impact of new technologies to perform in virtual-reality environments. This approach will visualize the capabilities of innovative technologies and methodologies that have initial-low TRLs but have the potential to enable step-changes and have a significant impact on the railway system.

During the project, we discussed and developed some potential concepts for such virtual reality tools based upon user needs which are also described in this deliverable. However, the actual development of the virtual reality tools was not carried out, as our analysis of the requirements indicated that there was not a need for such a tool and most of the objectives could be achieved with existing tools or other tools which are currently under development. The area in which SP5 could have created a new tool would have been in creating an easy to use interface to the cost-benefit analysis work carried out within WP5.4, however, due to the high level of customisation required for each innovation and case study, the architecture of the tool would have had to have been reconsidered and was beyond the scope of what was possible within the project.

1 Objectives

The objective of Task 5.5.5 is described in the grant agreement as:

Demonstration of the impact of new technologies will be performed in virtual-reality environments. This approach will visualize the capabilities of innovative technologies and methodologies that have initial-low TRLs but have the potential to enable step-changes and have a significant impact on the railway system.

To help better define the objective of this task and analysis of requirements and solutions has been carried out, looking at the potential users for such a tool and their user stories (a common methodology used in software development) which would be used to help identify their requirements. These requirements have been developed into concepts for the demonstration and then section 4 of this report describes the types of technologies that had been considered for the demonstration in a virtual environment. And lastly a discussion is included which describes the existing tools or tools under development which satisfy these requirements.

2 Users and Requirements

Identified potential end users of the demonstration in a virtual environment are

- o Timetablers and train operators
- o Asset managers
- o Financial planners
- o Government/Regulators
- o Track engineers/work planners

The following sections describe a user story for each group of potential end users and the derive requirements.

2.1 TIMETABLERS AND TRAIN OPERATORS

User story

The timetabler uses the tool to display the disruption caused during the migration phase of the installation of an innovation. This tool would show the possibilities for traffic diversions and the requirements for traffic diversions and the requirements for on road rail replacement services, as well as the impact on journey times, capacity and rail system reliability.

Requirements

- Display disruption caused during migration to new innovations
- Show possibilities for traffic diversions
- Show the requirements for non-rail replacement services for passengers and freight
- Show the impact of the innovations and the migration phase on journey times, capacity and rail system reliability

2.2 ASSET MANAGERS

User story

The asset manager uses a demonstration in a virtual environment tool to understand the innovations impact on the life of the track components, overall maintenance costs, whole life cycle costs and other targets such as reliability, capacity etc. The asset manager also uses a separate tool to identify bottlenecks and areas where the costs, reliability of components or life of components are extraordinary. A third tool which is used by the asset manager are simulations which help to provide the asset manager and engineers with information related to the innovations failure mechanisms and through simulations determine the stresses and likely life of components.

Requirements

- Understand the impact of innovation on:
  - o Life of track components
  - o Overall maintenance costs
  - o Whole life cycle costs
  - o Reliability

- o Capacity
- Identify bottlenecks in the systems related to capacity
- Identify where components life is extraordinary (either longer than usual or shorter than usual)
- Understand the physical behaviour of innovations and relate this to potential failure mechanisms

2.3 FINANCIAL PLANNERS

User story

The financial planner used a tool to determine the overall cost over the life time of particular innovations or to plan forthcoming financial commitments during the installation and migration to a new technology. This tool demonstrates the costs associated with a particular innovation and when these costs occur during a product lifecycle.

Requirements

- Identify costs associated with innovations
- Identify when the costs will occur during a project life cycle.

2.4 ROLLING STOCK

User story

Government/Rail Regulators use a tool determine who is pays for the costs and who benefits from the innovations and therefore how benefits may be shared with those who are impacted by the cost of the innovation, e.g. through reduced track access charges. The tool demonstrates the breakdown of costs and benefits by the different actors in the railway, e.g. infrastructure managers, train operating companies, rolling stock owning companies etc.

Requirements

- Identify the costs and benefits associated with the different railway actors

2.5 TRACK ENGINEERS AND WORKS PLANNERS

User story

Track engineer and works planners can use this virtual reality environment to plan the movement of machinery and personnel on a work site, identify using virtual reality whether there are any structural gauging issues with any of the machinery or parts. This is particularly relevant for cases of modular slab track to assess the access to site for the large track components.

Requirements

- Identify any structural gauging clashes with either machinery or track components
- Plan the movement of machinery and personnel on a work site

2.6 REQUIREMENTS MATCHED TO TYPES OF TOOLS

The following Table 2 summarizes the requirements the proposed type of tools and the users.

TABLE 1 RELATION BETWEEN REQUIREMENTS TOOLS AND USERS

REQUIREMENTS	TYPE OF TOOL	USERS
• Display disruption caused during migration to new innovations • Show possibilities for traffic diversions • Show the requirements for non-rail replacement services for passengers and freight • Show the impact of the innovations and the migration phase on journey times, capacity and rail system reliability • Identify bottlenecks in the systems related to capacity	Network traffic simulator	Timetablers/ Train Operators Asset Manager
• Understand the impact of innovation on: o Life of track components o Overall maintenance costs o Whole life cycle costs o Reliability o Capacity	Multi-criteria assessment tool	Asset Manager
• Identify where components life is extraordinary (either longer than usual or shorter than usual)	GIS visualization tool for existing data and for innovations	Asset Manager
• Understand the physical behaviour of innovations and relate this to potential failure mechanisms	Finite element modelling	Asset Manager
• Identify the costs and benefits associated with the different railway actors • Identify costs associated with innovations • Identify when the costs will occur during a project life cycle.	Cost benefit assessment tool with costs and benefits broken down by the different railway actors	Asset Manager Financial Planner Government/Rail Regulators
• Identify any structural gauging clashes with either machinery or track components • Plan the movement of machinery and personnel on a work site	Virtual reality 3D animation of a work site	Track Engineers/Works planners

2.7 USABILITY

The following **Table 2** summarizes some aspects with respect to the usability of a virtual demonstration tool.

TABLE 2 REQUIREMENTS WITH RESPECT TO USABILITY

Feature	Requirements
Comprehensibility	The product documentation is system documentation, operating manual, user manual, possibly release notes.
Learnability	• The operation of the product requires no special requirements or capabilities of the user. • The basic handling of a PC system (Windows, IOS, LINUX) as well as knowledge of the Expertise is required. • Training is required by the client.
Usability and support	• Possibilities of personal configurability • Single point of contact and 1st level support • Professional second-level support is provided by the client / customer • User account
Attractiveness	• The tool shall be configurable in the design • The user interfaces are understandable and appealing
Multilingualism	The user interface should provide the configuration for different languages

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3 Summary of ideas for this demonstration

Network traffic simulator

- A network traffic simulator would demonstrate the impact of the innovations on capacity and the traffic movements, such a simulator would also be able to demonstrate the impact of the migration on rail traffic and indicate the scale of train cancellations or the diversion of traffic to other routes on the network or on to the road.

- This type of simulator is similar to the BRaVE (Birmingham Railway Virtual Environment) simulator, RailSys or HERMES by Graphica, and these types of models are already being further developed within SP3 of Capacity4Rail.

Multi-criteria assessment tool

- A multi-criteria assessment tool would allow for different technologies to be assessed against a multitude of different criteria and allow for each of these to be scaled and scored, to allow decisions to be made which may for example want to put a higher weight to capacity improvements over for example whole life cycle costs. Further tools would be required to feed data into a multi-criteria assessment tool such as capacity data from a network traffic simulator and cost data from a life cycle cost assessment.

- Original plans included developing such a multi-criteria assessment tool within WP5.4 of Capcity4Rail, and detailed descriptions of this can be found within deliverable D5.4.1. However, a similar tool was also being developed as a web based tool within SP3 of Capacity4Rail, and rather than duplicate this within SP5 the main work in developing a multi-criteria assessment tool were carried out within SP3.

GIS visualization tool for existing data and for innovations

- A GIS visualization tool would allow for data to be analysed geographically, for example it would allow a visual representation on a map of the costs of infrastructure, traffic, capacity, reliability data and would help track engineers to identify where bottlenecks may occur, or to identify problematic areas which lead to poor levels of reliability.

- Existing tools are in development which allow this type of GIS visualization to be carried out using existing railway data. For example, the RailVIVID and RailTopoModel software fits into this category, and further development is being carried out within the NeTIRail-INFRA H2020 project to develop a web based tool, which will allow for the import of data from existing databases, such as the RNIF database, as well as custom data. The NeTIRail-INFRA tool will also match appropriate technologies to the climate and traffic conditions to act as a decision support tool allowing asset managers to select the most appropriate innovations to their local climate and traffic conditions.

Finite element modelling

- Finite element modelling allows track based innovations such as the innovate slab track and switch and crossings to be modelled in 3D and analysed for the stresses and dynamic responses which would lead either to component failure or derailment risk.
- Within the Capacity4Rail project finite element models have been created for the SP1 innovations where they are relevant.

Cost benefit assessment tool with costs and benefits broken down by the different railway actors

- A life cycle cost assessment tool could be improved with easier tools to interpret the results and allow for easy manipulation of the data, for example easy implementation of sensitivity analysis or Monte Carlo simulations around the existing data. For the railway industry it is also important to clearly identify which part of the industry e.g. infrastructure manager or operator would see which costs and which benefits.
- Although tools exist which aid life cycle cost assessments, e.g. D-LCC, and create easy templates for sensitivity analysis, there is much potential for a tool customized to the railway industry and has the potential to build upon the work created within Capacity4Rail WP5.4.

Virtual reality 3D animation of a work site and migration scenario

- A tool which can used to visual the implementation of a new technology, showing the stages of construction and the movement of plant and materials, as well as demonstrating the migration stages would be extremely useful in the railway industry, especially during the planning of major works.
- The construction of such tools requires specialist development expertise, which is not available in the Capacity4Rail consortium.

4 Possible technologies and software

The analysis of the types of tools currently available or already under development within the Capacity4Rail project or other EC funded projects, and based on the skills available within the Capacity4Rail project led to the conclusion that the most feasible and useful virtual demonstration would be to build upon the work carried out within WP5.4 of Capacity4Rail and develop a user friendly front end to the life cycle cost analysis.

The life cycle cost analysis within WP5.4 was carried out using complex, customized excel spreadsheets and the concept included developing front end that would either work with the excel based cost benefit analysis or replicate the functionality of the WP5.4 excel spreadsheet in another tool.

Types of software identified for building the front end include:

- Visual basic interfaces and controllers, built upon the excel spreadsheet
- Shiny - based on R in the background
- Matlab
- GIS based tools such as ArcGIS or QGIS to plot cost benefit analysis data onto a geographical map, with either excel running in the back end to generate the data

The user interface would consist of initial screens prompting the user to either import the relevant cost benefit data, data related to traffic, life of the track components, route scenario, signalling systems, environmental impacts etc.

Then the results interfaces would present these results in a graphical form, providing user controls to manipulate the data and try different scenarios, sensitivity analysis or run Monte Carlo simulations.

However, it was found that during the development of WP5.4 the cost-benefit analysis spreadsheets required considerable customization for each scenario and innovations and therefore the development of a standardized tool would be very complex and require a completely new architecture to the solution developed within WP5.4.

4.1 MAKE OR BUY

During the project the question was raised whether to make or buy a toolbox or user interface for virtual demonstration. This question is, especially with respect to further usage of the tools after C4R, of great importance.

At the end of the day the best solution for the virtual demonstration is to implement existing tools in a user-friendly interface and to use external support for the integration. This approach allows further developments and ensures support in case of any problems.

5 Conclusions

Within WP5.5 various solutions for demonstration within a virtual environment have been considered, the requirements have been built up from user stories and then used to identify the types of tools that could meet these requirements. It has been shown that many of the tools were already in development or had been used within SP1 and SP3 of Capacity4Rail whilst others were commercially available or under development within other EC funded projects.

Two types of tools were identified which would fill a gap in the market and these were:

- Cost benefit assessment tool with costs and benefits broken down by the different railway actors and customized to the railway industry
- Virtual reality 3D animation of a work site and migration scenario

The virtual reality 3D animation of a work site and migration scenarios, was outside of the skills within SP5 of the Capacity4Rail project. However, developing a user interface to the cost benefit work carried out within WP5.4 was considered and ideas developed for this. However, due to the customization required for each Capacity4Rail innovation and scenario it was determined that it would be difficult to simply translate the WP5.4 work into such a new tool and considerable work would have been required to redesign the architecture behind this tool.

6 References

[1]   NeTIRail-INFRA H2020 project, 2015; http://netirail.eu/

[2]   Shiny – R; https://shiny.rstudio.com/

[3]   MATLAB; https://de.mathworks.com/

[4]   ArcGIS; https://www.arcgis.com/features/index.html

[5]   QGIS; http://www.norbit.de/64/