Deliverable D7.6
Overview of project related recommended future development needs.

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Lead contractor

UIC

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Executive Summary

NeTIRail-INFRA developed many technologies during the three years of the project, and is providing a route for further research actions. Throughout the project, opportunities for further developing smart technologies arose. However, research is not limited to technologies, but also includes their socio-economic evaluation if it is to result in applications in the field, or standards development. The present deliverable recommends concrete topics of future developments that would extend NeTIRail-INFRA research actions.

Based on a list of deliverables representative of NeTIRail-INFRA’s main innovations, the present deliverable uses Technology Readiness Levels to quantify the level of innovations reached at the end of the project, as well as the level of innovations that would be reached after the recommended further developments are implemented. Only the immediate and realistic next steps have been examined, as the developments suggested in this deliverable would themselves call for further developments until a full Technology Readiness Level of 9 is reached.

This deliverable is closely related to deliverable D7.5 “Overview of technical developments and innovation with direct or possible future expected impact on existing guidelines”. Indeed D7.5 is proposing future actions of standardisation and guidelines updates, which are not directly research actions, but which also call for further exploitation of NeTIRail-INFRA results, both deliverables D7.5 and D7.6 targeting at making technology choices for reaching a maturity level that would allow market uptake.

This deliverable has no deviation from the grant agreement.
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1. Introduction

NetIRail-INFRA developed many technologies during the three years of the project and provides a route for further research actions. Throughout the project, opportunities for further developing smart technologies arose. However, research is not limited to technologies, but also includes their socio-economic evaluation.

The deliverable is recommending concrete topics of future development that would extend NetIRail research actions.

2. Methodology

NetIRail-INFRA has two main components:
- Technical innovations in a number of sectors;
- Evaluation tools to assess the relevance of the innovations (WP1, WPS, WP6).

The future developments of technical innovations would basically tend into two directions:
- Refined technological choices or search for alternatives; purpose would be to improve the Technology Readiness Level (TRL); only the immediate, realistic next step should be proposed, possibly implying a jump by several TRL levels.
- Making technology choices market-ready, e.g. via standardisation: see Deliverable D7.5 “Overview of technical developments and innovation with direct or possible future expected impact on existing guidelines”.

The document is based on a list of deliverables representative of NetIRail-INFRA’s main innovations. The identification of the relevant deliverables has been performed in close cooperation with the NetIRail coordinator who has the overview of all deliverables developed by the project.

Where a topic description refers to a Technology Readiness Levels (TRL), the following definitions apply [1]:
- TRL 1 – Basic principles observed.
- TRL 2 – Technology concept formulated.
- TRL 3 – Experimental proof of concept.
- TRL 4 – Technology validated in lab.
- TRL 5 – Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 6 – Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 7 – System prototype demonstration in operational environment.
- TRL 8 – System complete and qualified.
- TRL 9 – Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).
3. WP1 - Contrasting market needs and business case

3.1 D1.6 - Wider economic benefits

Deliverable D1.6 “Wider economic benefits final report” has reached a TRL level of 6 through demonstration on case study lines.

Next step action

- Extended study on the interaction between employment effects and the rail investments, and further research on the link with land use.
- Development of a model of the interaction between rail investment and employment. This would include looking at data from historical rail investments and identifying regional changes to employment, and develop a model based on the correlation of rail investment and employment, as well as other factors which may influence employment data (e.g. normalise for changes in employment in the general population).

TRL level after next step action

Prototype of the model - TRL 7.

3.2 D1.7 - Incentives

Deliverable D1.7 “Incentives final report” has reached a TRL level of 6 through demonstration on case study lines.

Next step actions

a) As of today, there is no comprehensive, public infrastructure data source relying on railML®. Awaiting the turn of events, the NeTIRail-INFRA consortium retained about ten “track quality” parameters provided by the European Register of Infrastructure (RINF). These data are in a stable format (the RINF xsd is published by the Agency website) and regularly updated. By “quality”, and following the usage of various sources, we mean the technical (nominal) characteristics of the tracks, not their actual age or state of repair.

Geospatial analysis of costs would be further improved by using other important data, for which sources have yet to be identified and/or made available:

- Traffic data, preferably by categories of trains;
- State of repair, e.g. using mass trackside-detected on onboard-detected data, as made possible through several NeTIRail innovations (see WP4).

Obviously, calibration of the cost prediction model and adaptation to national conditions (currently proposed via a single cost correction factor) would be needed to make sense of extended data usage.

b) Concerning the relation between cost modelling and the application of lean automotive industry techniques, it is expected that wastes could be eliminated from the planning process. It is therefore recommended that the planning process should be studied further in the future and built upon the work carried out in the AUTOMAIN [2] project for tamping operations. AUTOMAIN identified the
complex interfaces and decision loops in the planning process, leading to significant waste, as well as the very long time periods over which the planning took place.

Concerning the relation between cost modelling and corrugation reduction strategies, the next steps of the research efforts would be focus on the further development of the 3D-FE model and then evaluate, by the design of a business case, the better use of the available information about corrugation.

**TRL level after next step action**

Prototype of the model(s) - TRL 7.

3.3 **D1.8 - Final business case synthesis**

Deliverable D1.8 “Final business case synthesis final report” has reached a TRL level of 6 through demonstration on case study lines.

**Next step actions**

The interaction between employment effects and rail only and rail plus land use investments is one area of further research.

A second area should be focusing on the development of employment models that can be used easily in appraisal and transferred between projects – for example one based on changes in economic density.

In the literature search on parameters for the agglomeration effects and imperfect competition effects, we also found that there is limited evidence on these effects in east European countries. Therefore, the need to develop that evidence remains.

**TRL level after next step action**

After the next steps of action identified above, the TRL remains at level 6, demonstration in case study lines. However, the scope of study will have widened to new areas.
4. WP2 - Tailored track infrastructure, design and maintenance

4.1 D2.2 - Practices and track technology tailored to particular lines
Deliverable D2.2 “Practices and track technology tailored to particular lines” has reached a TRL level of 3 through guidelines to help choosing the best solution which are still to be validated.

Next step actions
- Infrastructure managers building on the guidelines and real decision making.
- Further research on the costing and benefit to be made.

TRL level after next step action
Use in the daily operations - TRL 9.

4.2 D2.3 - Cost/benefit data and methodology for lean in S&C
Deliverable D2.3 “Cost/benefit data and application methodology for lean in railway S&C” has reached a TRL level of 7 through the methodology applied in the field.

Next step action
Infrastructure managers to use lean techniques.

TRL level after next step action
Use in the daily operations - TRL 9.

4.3 D2.4 - Lean and automotive industry techniques for S&C
Deliverable D2.4 “Application of lean and automotive industry techniques to produce a step change in railway S&C life and costs” has reached a TRL level of 2 through concepts for optimisation of the switch and crossings installations.

Next step action
Further development of these concepts and trial in real case studies.

TRL level after next step action
Demonstration of the benefits of optimisation in a real environment - TRL 6.

4.4 D2.5 - Corrugation reduction strategies & D2.6 - Tailoring track to avoid corrugations
Deliverables D2.5 “Corrugation reduction strategies for NeTIRail track types, with and estimates of costs and benefits” and D2.6 “Tailoring track to avoid corrugations: Traffic dependant selection of rail
cross section, clips and pads to avoid or delay corrugation” have reached a TRL level of 7 through the prototype tested in Turkey.

Next step action

Further development of the track model, with increased sophistication for modelling longitudinal support, however, more real parameters need to be obtained experimentally of both the track and dynamic conditions to verify the dynamic responses in the model.

TRL level after next step action

Same TRL level but with a more advanced model - TRL 7.

4.5 D2.7 - Lubrication systems and data & D2.8 - Tailoring lubrication to duty and climate

Deliverables D2.7 “Lubrication systems and data available, with estimates of costs and benefits” and D2.8 “Tailoring lubrication to duty and climate: Safe, effective and eco-friendly avoidance of track wear and damage” have reached a TRL level of 3 through guidelines to help choosing the best solution, which are still to be validated.

Next step actions

- Infrastructure managers building on the guidelines, and integrating the lubrication selection process into their internal procedures for real decision making of the type of lubrication device and lubricant for different line types and climates.
- Further research on the costing and on observed benefits should be undertaken.

TRL level after next step action

Use in the daily operations - TRL 9.

4.6 D2.9 - Transition zone model & D2.10 - Cost effective transition zone design

Deliverables D2.9 “Preliminary transition zone model and detailed modelling plan” and D2.10 “Cost effective transition zone design tailored to line type and traffic” have reached a TRL level of 3 through experimental proof of concept on the aspect of modifying the sleeper mass.

Next step action

Further modelling and validation.

TRL level after next step action

Technology validated in relevant environment - TRL5. To take it to TRL7, this would require real life testing.
5. WP3 - Tailored overhead line power supply infrastructure

5.1 D3.3 - Resilience of power supply infrastructure to changing climate & D3.4 - Modular packages for new installations of power infrastructure

Deliverables D3.3 “Model to support increasing the resilience of power supply infrastructure to changing climate” and D3.4 “Modular packages of component grades and design specifications for new installations of power infrastructure tailored to traffic and operational needs” have reached a TRL level of 3 through guidelines to help choosing the best solution, and still need to be validated.

Next step actions

- Infrastructure managers to adopt the guidelines recommended in deliverable D3.4, integrate them into their selection and procurement processes and adopt them for real decision making.
- Further research on the costing and observed benefits should be undertaken.

TRL level after next step action

Use in the daily operations - TRL 9.

5.2 D3.5 - Wire tension, pantograph collector strip and upload force & D3.6 - Data on system damage

Deliverable D3.5 “Tailored combinations of wire tension, pantograph collector strip material and upload force for optimum performance” and D3.6 “Data on system damage for different combinations of wire tension, pantograph collector strip material and upload force” have reached a TRL level of 4 through the model on wire tension which was validated, and a TRL level of 7 through the prototype validated in relevant environment for the sensor.

Next step actions

- Concerning the model, further refinement and validation is required, this includes validating the model at a greater range of conditions, e.g. vehicle speeds and effects and investigating a number of other overhead line designs. An area of future development would be to investigate inerter technology in the catenary system for damping the overhead line dynamics, this could be especially interesting for two pantographs running of high speed rolling stock, however, during NeTIRail-INFRA project the inclusion of inerters into the model was not possible.
- Concerning the sensor, the sensors should be tested more widely in more contact wire locations and with different train and pantograph types, it should also be tested against a greater range of rolling stock speeds. If necessary the sensors should also be redesigned for mass production, and wider installation should take place.

TRL level after next step action

6. **WP4 - Monitoring and Smart Technology**

6.1 **D4.1 - Data collection equipment & D4.2 - Low cost track-based monitoring for plain line and S&C**

Deliverables D4.1 “Data collection equipment in the laboratory environment, and plan for field trials” and D4.2 “Low cost track-based monitoring modules for plain line and S&C” have reached a TRL level of 7 through validation in relevant environment.

**Next step actions**
- Further testing and scaling up production.
- Correlating measurement data with maintenance requirements.

**TRL level after next step action**
Market uptake of the product - TRL 9.

6.2 **D4.3 - Track and ride quality monitoring & D4.4 - Track and ride quality monitoring based on train-borne measurements**

Deliverables D4.3 “Development of technology for track and ride quality monitoring” and D4.4 “Track and ride quality monitoring technology based on train-borne measurements in standard vehicles” have reached a TRL level of 8 through the ABA system which has been better calibrated (system complete and validated).

**Next step action**
Wider adoption of the system.

**TRL level after next step action**
Market uptake of the product - TRL 9.

6.3 **D4.5 - Smartphone technology for track and ride quality monitoring & D4.6 - Low cost smartphone track and ride quality monitoring**

Deliverable D4.5 “Development status of smartphone technology for track and ride quality monitoring” and D4.6 “Low cost smartphone-based track and ride quality monitoring technology” have reached a TRL level of 7 through validation in relevant environment.

**Next step actions**
- Further testing and scaling up production.
- Correlating measurement data with maintenance requirements.
6.4 **D4.7 - Harmonised interface to transmit on-board monitoring data to the traffic control centre**

Deliverable D4.7 “Harmonised interface to transmit on-board monitoring data to the traffic control centre” has reached a TRL level of 7 through system prototype demonstration in a relevant environment.

**Next step action**
Looking for possible standardisation in order to make wider adoption of the system possible.

**TRL level after next step action**
Market uptake of the product - TRL 9.

6.5 **D4.8 - Specification for simplified interlocking of user autonomous switches in low density lines**

Deliverable D4.8 “Functional, operational and technical specification for simplified interlocking of user autonomous switches in low density lines” has reached a TRL level of 7 through system prototype demonstration in a relevant environment.

**Next step action**
Looking for possible standardisation in order to make possible a wider adoption of the system.

Investigate the need for, the choice of, and the way to use Common Safety Methods (CSM) on risk assessment in relation with the introduction of this technology.

**TRL level after next step action**
Market uptake of the product - TRL 9.

6.6 **D4.9 - Interface definition for input of GNSS location data to monitoring technology**

Deliverable D4.9 “Interface definition for input of GNSS (or ground-based train odometry) location data to monitoring technology” has reached a TRL level of 7 through system prototype demonstration in a relevant environment.

**Next step action**
Looking for possible standardisation in order to make a wider adoption of the system possible.

**TRL level after next step action**
Market uptake of the product - TRL 9.
6.7 D4.10 - Tailored decision support for track and vehicle maintenance through conversion of data to information

Deliverable D4.10 “Tailored decision support for track and vehicle maintenance through conversion of data to information” has reached a TRL level of 2 through concepts for tailoring the decision support for track and vehicle maintenance.

Next step action

Further modelling and validation.

TRL level after next step action

Validation in relevant environment - TRL 5.
7. WP5 - Societal perspective: D5.3 - Societal effects & cost benefit of infrastructure decisions

Deliverable D5.3 “Balancing societal effects and cost benefit of different infrastructure decisions” has reached a TRL of level 6, through demonstration of the process on case study lines.

Next step action

In this deliverable, the Social Impact Assessment (SIA) for each of the NeTIRail-INFRA innovations on an exemplary line has been conducted, selected among the NeTIRail-INFRA case-studies, because it presents characteristics that make the assessment particularly interesting. The results of the SIA have been combined with the Cost-Benefit Analysis (CBA) for each innovation and, in the last section, an example was provided on how these can be used as guidelines for transport decision.

The next steps consist in expanding the combined economic and societal analysis to other combinations innovation/line and presenting their results in the GIS web tool developed in WP6.

TRL level after next step action

After the next steps, the innovation in Societal effects would remain at TRL 6, although it would have been generalised, however it remains at the level of demonstration on a case study line.
8. **WP 6 - Evaluation and decision support tools**

All TRLs in this section related to the online GIS application, at its different stages of development, and of the data input used by said application.

### 8.1 D6.3 - GIS-based application & D6.4 - Decision support tools

Deliverables D6.3 “GIS-based web Application” and D6.4 “Decision support tools for implementation of technologies” have reached a TRL level of 6 through demonstration in relevant environment, but not yet fully tested and calibrated.

The deliverable is one single Web Application, comprising the works under T6.1, T6.2, T6.3, and including the application, sample datasets, and scenario player (D6.2, D6.3, D6.4).

**Next step action**

Taking over the elements of D1.3 to generalize the cost benefit analysis (not only the cost aspects) so that the output is available over the whole map with a reasonable (= to the order of magnitude) precision level.

An even further step would be to allow the user to input his ‘own’ formulas using a dedicated language and a small parser integrated into the application. In the current implementation, the cost prediction formula is made accessible to the administrator as Python executable code (technically, a character string). It would be fairly easy (but for security testing) to provide the end user with the same functionality, assuming fair Python knowledge on his part. Such a solution is already used by other GIS software such as QGIS, that uses Python as a scripting language.

**TRL level after next step action**

Demonstration in operational environment - TRL 7.

### 8.2 D6.7 - Current design & maintenance criteria relative to needs, static illustration for case study lines

Deliverable D6.7 “Status report on current design & maintenance criteria relative to needs, static illustration for case study lines” has reached a TRL level of 3 through experimental proof of concept.

The deliverable is a status report on design & maintenance criteria relative to needs; static illustration for case study lines.

**Next step action**

Extending the database used by the web application, so that maintenance policies and the state of the infrastructure are reflected there. This is indeed the information that D6.7 is supposed to capture. Updating the application so that such data can be input and displayed.

**TRL level after next step action**

TRL 4 – Technology validated in lab (well-functioning application, using sample data). Whether the additional information can be made available, would condition the next levels.
9. Conclusion

NeTIRail-INFRA developed many technologies during the three years of the project and provides a route for further research actions. Throughout the project, opportunities for further developing smart technologies arose. However, research is not limited to technologies, but also includes their socio-economic evaluation. The deliverable has recommended concrete topics of future developments that would extend NeTIRail research actions.

Based on a list of deliverables representative of NeTIRail-INFRA’s main innovations, the deliverable used Technology Readiness Levels to quantify the level of innovations reached at the end of the project as well as the level of innovations that would be reached after the proposed recommendations of further developments are implemented. Only the immediate and realistic next steps have been proposed, as the developments suggested in this deliverable would themselves call for further developments until a full Technology Readiness Level of 9 is reached.

This deliverable is closely related to deliverable D7.5 “Overview of technical developments and innovation with direct or possible future expected impact on existing guidelines”. Indeed D7.5 is proposing future actions of standardisation and guidelines updates, which are not directly research actions, but which also call for further exploitation of NeTIRail-INFRA results, both deliverables D7.5 and D7.6 targeting at making technology choices reach a maturity level as close as possible to market uptake.

10. References
