Transport Research Arena (TRA) Conference

Effectiveness of EU-funded R&I programmes from the perspective of the European railway sector stakeholders

Alessio Tardivo[a*], Andreas Pfeifer[b], Anh Hoang[b], Armando Carrillo Zanuy[a], Bastian Schick[c], Christian Schindler[b], Nils Jendrny[b], Nils Nießen[b], Oskar Froidh[c], Sebastian Stichel[c]

[a]EURNEX e.V., Hardenbergstraße 12, Berlin, D-10623, Germany
[b]RWTH Aachen University, Templergraben 55, Aachen 52062, Germany
[c]KTH Royal Institute of Technology, Brinellvagen 8, Stockholm 100 44, Sweden

Abstract

The paper provides a methodology for measuring the adherence of Research & Innovation (R&I) actions in railways to the stakeholders' requirements and expected benefits. After collecting the stakeholders' requirements, the R&I objectives are extracted from high-level documents such as Europe's Rail Joint Undertaking Master Plan and Multi Annual Work Programme. Lastly, after standardization of the requirements and the technology concepts, a top-down analysis is performed. The results show that network management and vehicle technologies have the highest benefit for the stakeholders, and ERRAC and Regulatory Bodies' requirements are well addressed. However, the end-users requirements are only partially fulfilled. The necessity of increasing multimodal transport and cooperation with other transport modes is shown, while stronger focus can be placed on the employees and education/training.

Keywords: Stakeholder analysis; Stakeholders requirements; Top-down analysis; EU-funded R&I programmes; R&I impacts and benefits.

1. Overview and motivation

While significant resources and numerous contributions have been undertaken to improve the efficiency and competitiveness of the railway sector in Europe, much less effort has been put into stakeholders' and users' perspectives, as indicated by Arnold (2012). Currently, the European railway sector lacks a framework of reference

---

* Corresponding author. Tel.: +39 333 976 2772.
 E-mail address: alessio@eurnex.eu

able to measure the adherence of Research and Innovation (R&I) actions to the stakeholders' requirements and the benefits they expect from being involved in these activities.

This research is directed toward developing such a framework to assess the long-term importance and evolution of the development areas pursued by the R&I actions. The resulting framework is expected to become a key milestone in the process of enabling better planning, monitoring and evaluation of EU-funded R&I actions and kick off a sound, fact-based, scientific discussion on the adherence of public research funds to the needs of the sector stakeholders. This paper, built upon the work performed within the Shift2Rail funded project Ben@Rail (grant agreement No 101046258) intends to bridge the existing knowledge gap by assessing the extent to which the technological and operational innovations foreseen by the Master Plan of the ERJU (Europe's Rail Joint Undertaking) responds to clear societal cases and produces benefits to the railway stakeholders and users.

As for the knowledge, objective and technological gaps, Shift2Rail has funded a previous project, TER4RAIL, which tangentially investigated the users' and stakeholders' perspectives and gaps from the EU rail research roadmaps. The project identified the following gaps and shortcomings with respect to the users and some rail stakeholders (policymakers), see Carrillo Zanuy (2021): **User perspective and on-demand mobility**. From the user perspective, it is stressed that there are shortcomings in the attempt to understand the needs and habits of the prospective users in a user-centred approach. **Policymakers**. The rail roadmaps do not adequately stress the need for political support in developing connectivity, infrastructure and hard technologies. **Multi-modal approach**. There is a need for rail to penetrate in other roadmaps (mainly road and maritime) to succeed with the implementation of common solutions.

The TER4RAIL project also performed a rational identification of rail stakeholders and complemented it with a vision of how they relate between each other and to other modes and sectors, see Herranz and Prieto (2019). As for the research and development objectives of the rail sector, the SRIA (Strategic Research and Innovation Agenda) by ERRAC (2020) is an agreed document of the rail sector platform in which the paramount necessities and roadmaps for future rail research are identified. A substantial part of the ERJU Master Plan emanated from this SRIA. High-level publications from other transport-related entities, such as the EU Agency for Railways (ERA), the Advisory Council for Aeronautics Research in Europe (ACARE) and the European Road Transport Research Advisory Council (ERTRAC), are also key in understanding the direction in which the future European railway system is headed.

Ben@Rail activities aim to ensure a tight adherence of the innovations stemming from Europe's Rail Joint Undertaking and its Master Plan to the needs of railway stakeholders and final users. In this context, this contribution aims at outlining a framework of reference for the evaluation of public-funded activities in the railway sector consisting of three elements: 1) The first element focusses on building a model that includes the stakeholders of the European railway system and their respective requirements. 2) The second element examines Europe's Rail JU Master Plan and the ERRAC SRIA to identify, extract and prepare to analyse those concepts that EU-funded projects are expected to develop. 3) In the third element, a top-down analysis is performed by comparing the stakeholders' expected benefits with the foreseen results developed within EU-funded projects.

2. Methodology

Overall, the study is characterized by a holistic approach to the sector, and the methodology reflects this aspect by allowing the evaluation of the concrete impacts and effects of EU-funded projects on each stakeholder within the railway system. Based on the ERRAC SRIA, the new ERJU Master Plan defines the key research and innovation trends that will characterize the European rail sector for achieving the Single European Railway Area and the EU objectives of Sustainable and Smart Mobility Strategy.

This study builds upon the available knowledge in the field of system development and refines a methodological framework suitable for assessing the effects of EU-funded R&I activities. Innovatively, this framework is able to provide evidence-based recommendations on the expected impact of the new Joint Undertaking Master Plan to the European policymakers and rail stakeholders. The methodology builds upon the product development process outlined by guideline VDI 2221, see Feldhusen and Grote (2013). The innovative contribution of Ben@Rail to the state-of-the-art of system analysis relies on the fact that, for the first time, a purpose-built scientific methodology has been employed to investigate the future outcomes of an EU-funding R&I programme, such as Europe's Rail, in a comprehensive way. Moreover, this study analysed the system's future while this very system (ERJU) is still being developed.

2.1. Analysis of relevant stakeholders and their requirements

To ensure that all relevant stakeholders are included in the analysis, work has focused on identifying the current and prospective relevant stakeholders with a legitimate interest in the railway system. After gathering the stakeholders, their requirements concerning the European railway system have been collected. The stakeholders and their requirements have been identified using creative and systematic methods like brainstorming and existing studies. Another method for collecting the requirements is the usage of checklists for setting up a requirement list, as described by Feldhusen and Grote (2013). This method provides a list of properties for a product (e.g., dimensions, kinematics, assembly, recycling, etc.) that can be used as inspiration for a complete list of requirements. For each sub-stakeholder, a first list of requirements was created by means of the methods mentioned and literature research. In addition, core requirements have been justified and derived from targeted interviews with stakeholder representatives for the main stakeholder categories. In this way, a comprehensive and valid representation of the requirements can be ensured.

After completing the collection, the requirements have been weighted to enhance their importance. Different stakeholders might have the same requirement but consider it with different importance, so each requirement is weighted for each stakeholder. In this way, different needs of different stakeholders can be considered. Furthermore, the analysis includes the types of requirements as to whether they might be mandatory or desirable. The weighting of the requirements was performed using a weighting scale that was defined between 0 and 3: where a requirement scored 0 points, it has no importance to the stakeholder, and, on the other hand, where a requirement scored 3 points, it has very high importance for the stakeholder. As for the gathering of requirements, the weighting was performed in targeted interviews with representatives of the main stakeholder categories. The weightings were complemented on the basis of the expertise of the project team and literature research. The results are summarized in a weighting matrix, which is further used in the methodology to perform the top-down analysis of the expected benefits.

2.2. Assessment of R&I objectives and their underlying benefits

To be able to compare the stakeholders' requirements analysis with the benefits that R&I activities are expected to yield, this research developed a structured overview of the expected R&I objectives. These objectives have been extracted from different documents, with the main focus on the "Europe's Rail Joint Undertaking Master Plan" (MP) and the "Europe's Rail Joint Undertaking Multi-Annual Work Programme" (MAWP). In addition, several documents have been analyzed to broaden the view of possible R&I objectives within the field of transportation technology. The additional documents include the ERRAC SRIA, publications from other research projects with background on topics adjacent to Ben@Rail, such as TER4RAIL and Mobility4EU, and strategic publications published by other organizations or other transport sectors, such as the EU Agency for Railways (ERA), the Advisory Council for Aeronautics Research in Europe (ACARE) or the European Road Transport Research Advisory Council (ERTRAC). These additional documents allow assessing the consistency of prioritized objectives between the MAWP and other recent strategic documents.

A top-down methodology has been employed to extract the objectives from the available documents. In particular, for their systematic analysis, a structure with five layers has been defined: 1) Envisioned benefits and impacts. 2) R&I objectives. 3) Specific concepts. 4) Individual innovations. 5) Technical examples.

The R&I objectives outline overarching categories of research work, showing connections between innovations and their importance for the rail system of the future. The specific concepts represent either new operational approaches that are supported by technical innovations or purely technical innovation categories. The involved innovations break down the specific concepts into more tangible systems or functions that are expected as research outputs. These systems or functions are exemplified in the final layer, which is not strictly limited to purely technical development, but can also include standards, architectures or operational routines.

From the extracted data, a list of all envisioned objectives and concepts has been compiled and compared against the stakeholder requirements identified previously. The structure of this list follows the main structural elements of the MAWP, the System Pillar (SP) and the Innovation Pillar (IP), which in turn is divided into seven Flagship Areas (FA), one Transversal Topic (TT) and Exploratory Research (ER).

The priorities of the structured R&I objectives and underlying layers have been assessed to the extent of available information. The Flagship Areas and other structural elements of the MAWP are grouped based on economic resource

allocation presented in the MAWP. On the layers of R&I objectives and specific concepts, the priorities for some cases are roughly estimated on a qualitative level.

Each extracted R&I objective is then related to several intended impact categories. For this, the seven impact targets defined in the MP are used to maintain a clear and relatable structure: 1) Meeting evolving customer requirements. 2) Improved performance and capacity. 3) Reduced costs. 4) More sustainable and resilient transport. 5) Harmonised approach to evolution and greater adaptability. 6) Reinforced role for rail in European transport and mobility. 7) Improved EU rail supply industry competitiveness.

The high-level analysis resulting from the abovementioned documents has assessed the consistency of overall objectives between the MAWP and other documents. Therefore, mainly strategic publications and deliverables from other Shift2Rail projects which formulate and summarize these desired research directions were studied. For this study, the chosen organizations are the EU Agency for Railways (ERA), the Advisory Council for Aeronautics Research in Europe (ACARE) and the European Road Transport Research Advisory Council (ERTRAC).

2.3. Top-down analysis of the expected benefits

Lastly, the methodology developed within this research focused on performing a top-down analysis of the relevant stakeholders and their requirements and expected benefits. In this last step, the research has merged the results from the previous two methodological steps, contrasting in a rating matrix both the stakeholders' requirements and the technological concepts identified within ERJU MP and MAWP. The rating matrix was created by rating the elaborated concepts from the R&I objectives assessment regarding the requirements gathered in the stakeholders' analysis. Therefore, an adapted rating scale was used in comparison to the weighting scale already employed in the stakeholders' analysis.

The rating scale was modified to a range from 0 to 1 point, where a concept that has been rated with 1 point has direct impact on the respective requirement. If a concept has an indirect impact on a requirement, it can score 0.5 points. A concept is rated with 0 points if there is no impact on a requirement at all. Finally, the concepts' ratings regarding the requirements were transferred into the rating matrix. The rating matrix was multiplied with the weighting matrix from the stakeholder's analysis to build the concept rating matrix (see Appendix A.).

By doing so, in this concept rating matrix a weighted rating for every concept regarding the stakeholders was created. For each concept, these weighted ratings were summed up to form a total weighted rating for each concept. With this methodology the concepts can be arranged hierarchically according to their total weighted rating, which built the core of the top-down analysis.

3. Results and main contributions

3.1. Results of the stakeholders and their requirements' analysis

A total of 13 different main stakeholder categories have been identified, and these main categories have been further divided into 44 sub-stakeholders. All stakeholders are presented systematically and structured graphically in a simplified stakeholder tree, as shown in Appendix B.

The research then extracted the respective requirements from the identified stakeholders, ordered and weighted them in a weighting matrix. This weighting matrix consists of 380 major requirements, followed by another 1100 unweighted minor requirements structured in their sub-layers

3.2. Results of the R&I structured overview

The extraction of the MAWP provided a total of 20 R&I objectives with 45 underlying research concepts, which are fully showcased in the document "Structured overview of R&I objectives and their underlying benefits" by Leeuw et al. (2022), see Appendix C.

These extractions and concepts show an overall good alignment with those mentioned in the other examined documents, where digitalization, automation, sustainability in manufacturing and operation, resilience, a holistic system approach and competitiveness of the European industry also play a central role. A few differences are noted,

for example in the area of user-centered development methods and services. They are recommended to be considered in the full top-down assessment that the project activities will develop.

The comparison between the ERRAC SRIA and the MAWP showed that five Flagship Areas (FAs) with the highest budget in the MAWP have a direct counterpart in the SRIA. Of the other areas in the SRIA, door-to-door mobility, considering public transport coordination and customer satisfaction, has the weakest representation in the MAWP. One FA, "Regional rail services / Innovative rail services to revitalise capillary lines", is new in the MAWP and not present as a separate entity in the SRIA.

3.3. Results of the top-down analysis

Overall, it can be seen that in particular the key areas FA 4 "Sustainable and green railroad system", FA 1 "Network and mobility management" and FA 3 "Intelligent and integrated asset management" can bring about the greatest fulfillment of the stakeholder requirements, as shown in Appendix D.

The top-down analysis performed reveals gaps and discrepancies between the conceptual implementation of the concepts and the requirements of the stakeholders, as seen in Appendix E. Based on these results, recommendations can be derived in a further step to what extent the conceptual orientation of the MP and MAWP should be calibrated.

The "end-user", as the main target group of the European Railway System, occupies only middle positions in the analyses performed. Therefore, to ensure end-user satisfaction, more direct efforts must be made to make the rail system affordable and highly reliable. Going further, an increase in end-user satisfaction could be achieved by focusing more on "door-to-door mobility" issues as well as "public transportation coordination." Another way to increase end-user satisfaction is to pay more attention to the requirements of the "infrastructure operator station". This stakeholder group is in one of the lower places in the ranking of the top-down analysis, as their main requirements of low cost and good accessibility of the station are only given secondary consideration in the concepts.

The top-down analysis clearly showed that employees are given a lower priority in terms of their needs being addressed. This coincides with the failure to address the needs of the education/training stakeholder. The inadequate addressing of these two stakeholders makes it clear that calibration at the concept level is required in this area. This seems increasingly important given the current situation in the employee and education market.

For the other transport modes, the main requirements are achieving multimodality, the adaptation of infrastructure for interoperability and a higher share of investment. These topics are addressed in FA 1, 6 and 7, but only with minor impact. In general, it can be suggested to strengthen the cooperation with other transport modes by lifting the impact on a more direct base. As there are approaches given in the concepts to create interoperability, these approaches need to be intensified to raise the alignment between the Other Transport Modes' perception and the concepts.

In the analysis carried out, the social benefit is not only to be derived from the main stakeholder Public/Society. Rather, other main stakeholders must be included for this purpose. Thus, the social benefit of the EU-funded R&I activities is further measured by the stakeholders Regulatory Bodies, Environment and Health, Organisations, R&I and Academia, Employees, Other Transport Modes and, of course, the End Users. The impact is therefore very complex and can be seen primarily in the fields of sustainability and digitization.

4. Conclusions and future works

In this paper, the authors detailed the methodology designed for composing a framework able to analyze the effectiveness of EU-funded projects within the railway sector from the stakeholders' and users' perspectives. The overarching objective of this framework is to measure the adherence of R&I actions to the stakeholders' requirements and the benefits they expect by being involved in these activities.

This paper, built upon the work performed within the Shift2Rail funded project Ben@Rail, proposes the three methodological steps that have been followed within the project activities and the final analysis regarding the effectiveness of R&I activities.

The analysis shows that thematic areas such as network management and vehicle technologies have the highest benefit for the stakeholders and that the requirements of ERRAC and Regulatory Bodies are very well addressed by the program. On the other hand, the requirements of the end-users are only partially fulfilled due to the derived indirect impact from the technology concepts of ERJU. As such, the end-users can be better addressed by strengthening the

Infrastructure Manager stakeholder (Station). The analysis points out a necessity of increasing multimodal transport and cooperation with other transport modes, particularly road and maritime transports considering logistics and passengers environments. Regarding the increasing shortage of qualified employees in the rail sector, the analysis recommends a stronger focus on the stakeholders representing Employees and Education/Training.

The framework resulting from these activities is expected to become a key milestone not only in the process of enabling a better planning, monitoring and evaluation of EU-funded R&I actions but also to kick-off a sound, fact-based, scientific discussion on the adherence of public research funds to the needs of the sector stakeholders. This framework is especially relevant not only for the railway sector to which it is applied in this instance, but also for other areas as well. Due to its scalability and replicability, Ben@Rail methodological approach can be applied to analyse the adherence between EU-funded R&I actions and the relevant stakeholders' and final users' expectations across various disciplines, amongst which healthcare, energy, urban development, European integration and others.
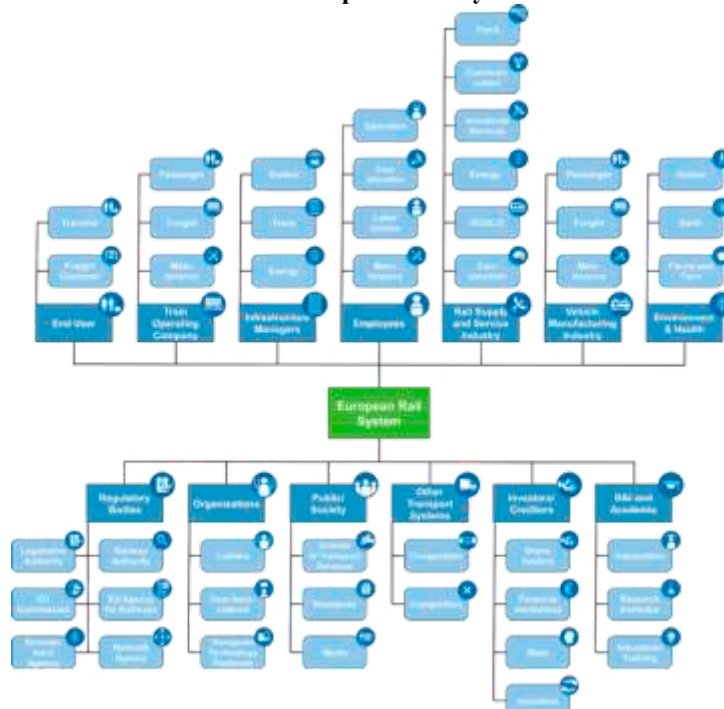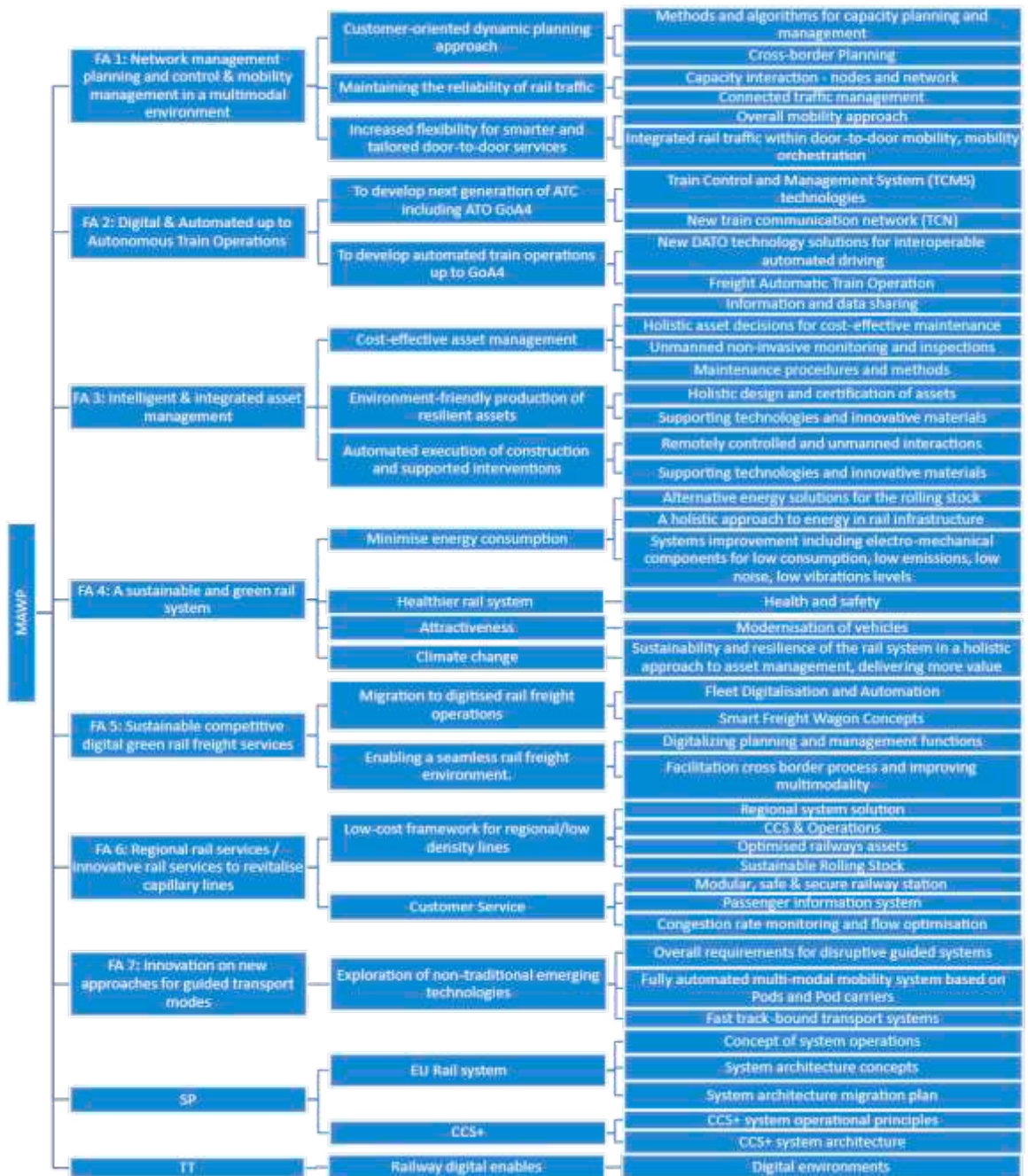
Acknowledgements

Appendix A. Exemplary calculation of the total weighted rating of concepts

## Appendix B. Simplified stakeholder tree of the European Rail System

Appendix C. Overview of the extracted structure of R&D objects in the MAWP (left column), with R&D goals (middle column) and specific concepts (right column)

Appendix D. Total percentage of benefit of the ERJU flagship areas examined (Total Weighted Rating)

Appendix E. Total weighted rating of each stakeholder
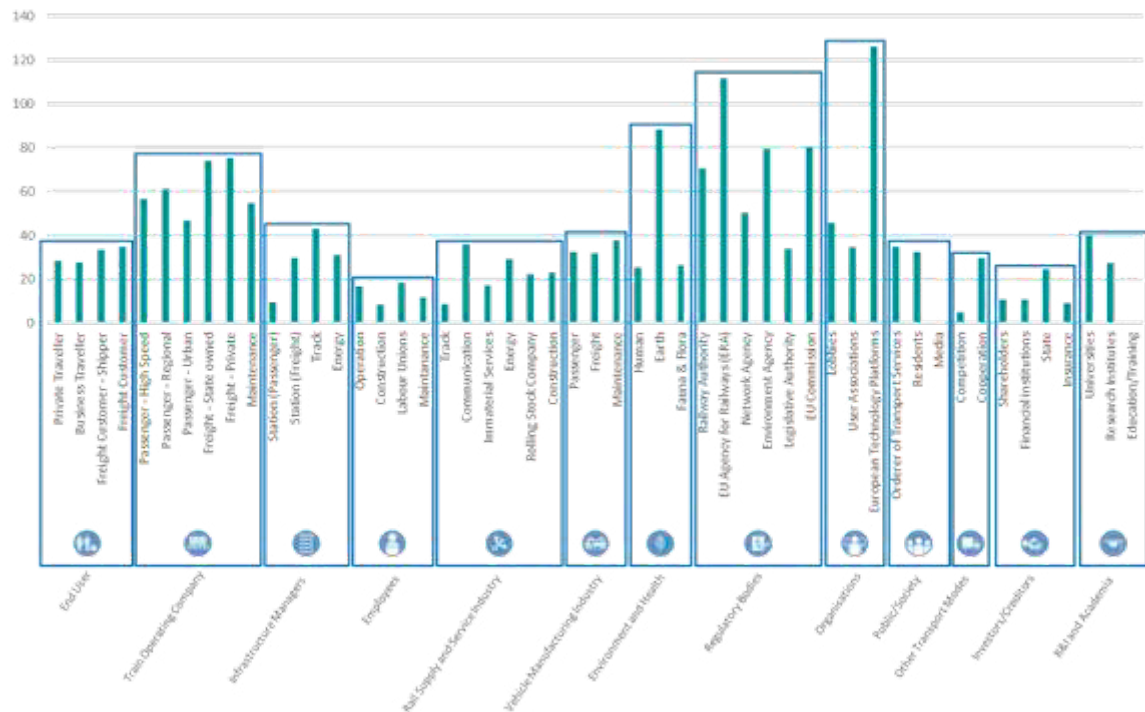
References

Arnold, E., 2012. Understanding long-term impacts of R&D funding: The EU framework programme. Research Evaluation 21.5, 332–343.

Carrillo Zanuy, A., 2021. Deliverable 2.2 - Review of the state of progress of roadmaps. TER4RAIL.

Herranz, A., Prieto, E., 2019. Deliverable 1.1 - A comprehensive map of rail innovative research and key rail stakeholders. TER4RAIL.

ERRAC: Rail Strategic Research & Innovation Agenda, 2020.

Feldhusen, J., Grote, K.H., 2013. Konstruktionslehre - Methoden und Anwendung erfolgreicher Produktentwicklung. Eds. 8, Springer Vieweg, Berlin, Heidelberg

Hoang, A., Jendrny, N., Pfeifer, A., 2022. Deliverable 1.1 – Simplified stakeholder tree and weighting matrix of requirements. Ben@Rail.

Leeuw, B., Djordjevic, B., Schick, B. and Stichel, S., 2022. Deliverable 2.1 – Structured overview of R&I objectives and their underlying benefits. Ben@Rail.