Current Gaps and Mismatches Between Rail Higher Education Provision and Industry Expectations

Carlos Casanueva Perez, Christian Matz, Borna Abramović, Denis Šipuš, David Calonge, and Kristina Svensson

Abstract The expectations of railway companies are not always aligned with the skills and abilities that university graduates bring when finishing their studies. This work firstly analyses the higher education study paths related to railways and their flexibility; then surveys the expectations of a set of European railway stakeholders in order to get the most looked after skills and abilities; next it analyses sectors other than the railways looking for academic best practices; and in the end it matches the most sought after skills within the Rail Careers Matrix for determining the relative importance of these skills in the operational, tactical, and strategic levels. The final result is a visual representation of the skills gaps and mismatches that European railway companies need to cover in the context of the actual Higher Education in the European landscape.

Keywords Rail higher education · Industry expecations · Mismatches

C. C. Perez (✉) · C. Matz
KTH Royal Institute of Technology, Stockholm, Sweden
e-mail: carlosc@kth.se

C. Matz
e-mail: christian.matz@alstomgroup.com

B. Abramović · D. Šipuš
University of Zagreb, Zagreb, Croatia
e-mail: babramovic@fpz.unizg.hr

D. Šipuš
e-mail: dsipus@fpz.unizg.hr

D. Calonge · K. Svensson
EURNEX, Southampton, UK
e-mail: david@eurnex.eu

K. Svensson
e-mail: kristina@eurnex.eu

M. Marinov et al. (eds.), *Sustainable Rail Transport 5*, Lecture Notes in Mobility,
https://doi.org/10.1007/978-3-031-51745-7_3

1 Introduction

Experienced recruiters in the rail industry face challenges when finding talent and personnel, as the skills and abilities that young graduates bring with them are most of the time not aligned with what these stakeholders need. Examples of this effect are specially visible in countries such as the UK (ARM, 2023) or Australia (Shepherd, 2022), but can be found all around the world (Smith, 2018). A study has been conducted to develop a better understanding of areas which are ill equipped with the necessary skills to find out current gaps and mismatches between rail industry expectations and higher education offerings. The work takes the educational benchmarking for railway studies and the industry requirements and expectations surveys and confronts them in order to understand the educational-job market pipeline and find out a common strategy towards developing and improving rail related education towards covering the existing perceived needs in the railway industry.

Additionally, other sectors might have already done similar studies, so educational setups from other specialities have been studied, including what implementations were done to improve the current subject-specific higher education teaching and learning practices.

1.1 Representation of Academic and Industrial Skills in the Railway Sector

In order to allow comparability with previous studies, a similar approach to SKILLFUL (2018) has been chosen, evaluating potential strengths and shortcomings of the used methodology and adapting the methods were necessary. The discussion about industrial skills is necessarily linked to the Rail Careers Matrix (Railway Talents, 2018) (Fig. 1), a visualization of the career opportunities in the railway industry. The application of the matrix in the context of the academic career paths is not direct though, as these are focused on thematic areas within the railway sector and not classic educational silos.

In SKILLLFUL (Ahern, 2017), new and emerging training tools, methodologies and schemes were identified and categorized in “Tools and technologies”, “Settings” and “Pedagogical model”. New innovative training scenarios had to be blended (using different tools and methodologies in the same course module) and learner centred (a more individually tailored learning opportunity for each trainee/learner). As these methods are rarely implemented nowadays, they complement traditional forms of teaching/training, instead of changing the training experience.

The COVID19 crisis in 2020 and 2021 boosted the implementation of distance/ubiquitous or asynchronous learning methods enormously. Although it’s difficult to support with empirical evidence, both teachers and students agree in claiming that a fully remote education is neither successful nor does it fulfil the participants needs

Fig. 1 Rail Careers Matrix (Railway Talents, 2018)

in other regards (Nikou & Maslov, 2021) further supporting the blended learning approach.

Regarding gaps in training for transportation careers, they used interviews and workshops to acquire knowledge about the industry's future needs and the current educational opportunities. "A training need is the gap between current and future knowledge and skills that can be bridged by training or learning activities" (Ahern, 2017). The results were presented in a table that displayed a short description of the gaps for different transport modes, and possible training methods to close these gaps. A summary of the rail sector is included in Table 1:

The rail career matrix (RCM) is represented in Fig. 1. UIC provides a thorough description for each matrix entry on its website (Railway Talents, 2018). The respective descriptions can be broadly summed up as listed in Table 2.

The use of the RCM (and derivative matrixes for the other modes of transport) in the SKILLFULL project seems to have led to rather broader outcomes. Other than expected, the gaps found were not specifically located in the matrix, but were listed in a broader way. Considering the small number of experts interviewed in the rail

Table 1 Gaps in the railway sector

Gap	Training tools/technologies/methodologies Nthat might be used to bridge this gap
New technologies and IT skills	Smart Learning Technologies Virtual Learning Environment (VLE) Heutagogy
Autonomous vehicles, connected vehicles	Virtual Learning Environment (VLE) Virtual/Augmented Reality Learning tools
Increased used of Augmented Reality in the workplace	Virtual/Augmented Reality Learning tools

Source SKILLFUL (Ahern, 2017)

Table 2 Description of matrix levels based on the Rail Talents description (Railway Talents, 2018)

Strategic	Tactical	Operational
• Representation and management duties, • Strong team-leading skills required, • Board member and decision maker • University degree and high level of experience required	• Liaison between operational and strategic • High levels of specific knowledge required • University degree not necessary • Team-leading skills required	• Mostly at-site and hands-on work • High level of practical, rail-specific skills required

sector and the overall (broad) scope of SKILLFUL, the results seem too broad and with a lack of specificity.

For the present work, using the RCM as a base seems natural. However, the current matrix certainly has its weaknesses when addressing educational programmes. In particular:

- Is a Traditionally biased matrix—the current matrix covers the traditional railway-related job fields. In present day, mostly through contemporary global challenges such as global warming and digitalization, new, emerging job groups might be necessary to complement the matrix.
- Is a career, not education matrix—the career focus of the RCM is evident. Required experiences in railways or other sectors are mentioned, whereas required educational backgrounds are rarely listed (almost exclusively for the tactical level). This way the RCM does not aim at freshly graduated students that don't have experience in applying their degrees in a specific sector.
- University education does not necessarily cover all levels of the matrix—the operational level is also served by other kinds of training or education, and there is arguably no direct access from university to a Strategic level position; for all Strategic and some Tactical positions, experience is required according to the matrix description.
- A specific university degree does not link to a specific area in the RCM—but opens a broad variety of different jobs. It is thus difficult to exactly assign programs to a certain matrix entry.
- Most positions do not require railway-specific education—non-railway-specific candidates may need longer initial internal training but can still staff the same position as a railway specialist.

Considering all mentioned shortcomings, there definitely is a need to review and adopt the matrix for the purposes of the present research program. There are two main aspects that should be addressed:

- Are the gaps in the industry needs visible and evident in the current Rail Careers Matrix, and does this need to be updated because of it?

- Is there a set of specific Study Paths that lead to specific RCM Careers? Can a more graduate-focused visualisation be implemented so that educational packages targeted are coupled with the actual needs of industry?

Still, the RCM is a tool that many stakeholders in the rail sector use, so if a review is performed the suggestion is to maintain the main configuration as much as possible to avoid the disruption of existing activities. The clearest objective is that the description of each level and area should be reviewed and rewritten considering the gaps and mismatches that appear between the descriptions and the industry needs.

2 Railway Education as a Preparation for a Job

When looking for the university-job market pipeline, the way higher education is organised in paths where students can take broad or more specialised courses and study programs. The first task is then to understand the possible study paths in different higher education institutions in Europe, if possible, splitting the railway systems knowledge into different thematic subsystems and how they eventually link to the different professional levels. This allows a sensible approach to understanding the position and perspective of different stakeholders when it comes to graduates as employees.

Additionally, and building over the training gaps and educational techniques in Table 1, other pedagogical techniques that can be applied to the railway education will also be explored, specially in how they link to an adequate transition to a railway job after graduation.

2.1 Educational Study Paths

In general, a bachelor program can be either used as a preparation for a master's or as direct access to the industry. To represent the available study paths in an academic institution, a matrix type of visualization is created (see Fig. 2). It consists of the available bachelor programmes (columns) and the available master programmes (rows) with '1' markers indicating that that specific bachelor program allows for unrestricted access to the respective master's program. If there is no direct access from bachelor's to master's the cell is left blank. The study paths are then grouped and highlighted in accordance with railway subsystems to give a more comprehensible visualisation.

The schemes produced this way are a more synthetic representation of the various study paths at different universities, which enables further discussions about the link between the study possibilities and the Rail Careers Matrix. The RCF is not directly an output of the railway study paths but guides the discussion by coupling educational paths and job experience via the grouping in subsystem thematic areas.

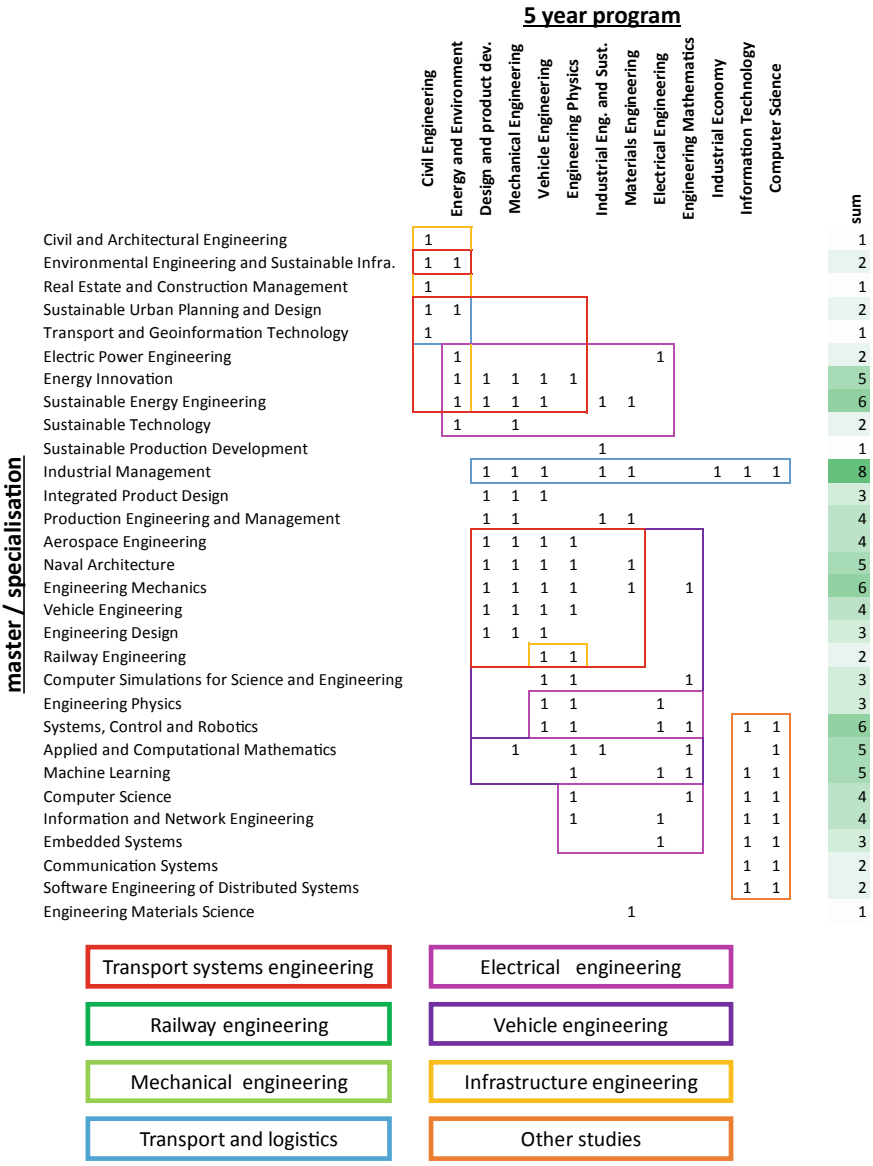

Fig. 2 KTH Matrix Study Path. The matrix suggests a high correlation between bachelors (or the first 3 years of a 5-year program) and master's, meaning only certain bachelor programmes allow to access a certain master's program

If the student decided to pursue a master's this allows them to either continue their studies with postgraduate courses and PhDs respectively, or to enter the industry directly. Due to their country-wise peculiarities, these are not considered in the study.

The matrixes and schemas of seven universities with railway-specific educational programmes or research units have been studied, and they reveal rather substantial differences among the available study paths at the different institutions. These differences concern the number and spectrum of programmes, the accessibility of master programmes, the availability of postmaster and PhD programmes, as well as the resulting job opportunities.

This variety of paths, with their different possibilities to reorientate during the studies, makes it challenging to draw a complete picture of all the railway-related study paths. What can be said though is that when starting in one of the generic fields of study from the railway subsystem classification, it is always possible to continue studying in this field up to the highest level (PhD).

Taking a closer look at what characterises a study path, we can conclude that it is arguably defined by its end. For students who end their studies after a bachelor's degree, a simple look at a university's list of bachelor programs gives the answer to the available study paths. For master studies, it is not only the area of the master program itself but also its accessibility from the bachelor's level. Or in other words, how easy is it to enter a certain master's program with a different bachelor's degree. We call this criterion "permeability".

We defined an integer scale from 0 to 3 to assess the permeability of the various master programs:

0 Master program(s) of this path not available.
1 Master program(s) of this path is only accessible with a bachelor from the same path.
2 Master program(s) of this path allow some permeability / are accessible with Bachelor's degrees from certain other paths.
3 Master program(s) of this path are accessible with bachelor's from nearly all other paths offered by the university.

Using this scale, we were able to draw a more complete picture of the actual availability of study paths at the institutions investigated (Fig. 3). Some study paths are rather narrow, meaning that it is not possible to end one's studies in this path when not already starting one's bachelors in the respective field. These are Mechanical Engineering, Infrastructure Engineering as well as Material Science. Others are highly permeable, given they are available. These are Transport and Logistics, Energy & Environmental Studies and to a certain degree also Transport Systems Engineering. The permeability of the remaining paths mostly depends on each institution. University of Zagreb stands out in this study, as all paths are highly permeable, allowing almost any bachelor student to continue in almost all master programs.

This raises the question of the definitions and limits of the different subfields from the railway's overview picture themselves. At various points in time during this study we were confronted with our own traditional perception of the railway industry. The fields apart from "other" indicate this. There are no fields called "Data Science",

		Areas / Paths										
		Traditional Rail related Paths							Other Paths			
		Transport and logistics	Transport Systems Engineering	Railway Engineering	Vehicle Engineering	Insfrastructure Engineering	Mechanical Engineering	Electrical Engineering	Computer Science	Management & Economics	Material Science	Energy & Environmental Studies
Institutions	La Sapienza (Rome, Italy)	2	3	0	2	1	1	3	2	1	1	2
	KTH (Stockholm, Sweden)	3	2	2	2	1	0	2	2	2	1	3
	Aston University (Birmingham, UK)	2	0	0	0	1	0	0	0	0	0	0
	TH Wildau (Wildau, Germany)*	2	0	0	0	0	2	0	1	2	0	0
	University of Ziline (Ziline, Slovakia)	1	2	2	1	1	1	1	1	1	0	0
	University of Malaga (Malaga, Spain)	3	2	0	2	0	0	0	1	1	1	3
	University of Zagreb (Zagreb, Serbia)	3	3	3	3	3	3	3	3	3	3	3

*does not offer PhD programs

Fig. 3 Study paths at the different universities including the permeability criterion

"IT", "Environmental Studies", "Project & Quality Management", "Security & Risk Management" and many others remain unnamed parts of "others". These are however important skills for the railway industry. We must thus admit that we did not capture all relevant rail-related fields in the railway overview picture and thus in the present study paths. We did however try to include some "others" when building this table.

Nevertheless, the railway overview picture and the present research remain important and useful as in many cases the missing fields listed above are considered necessary additions to more traditional studies. Engineers and logisticians are expected to not only fulfil the traditional requirements but to have versatile complementary knowledge beyond.

2.2 Teaching Methods for Future Professionals

The training gaps highlighted in previous projects showcase the most visible shortages, with possibilities for training these with pedagogical techniques. There are other underused techniques that could also be applied to the railway education, such as:

- Remote learning—this is useful in a sector where many practising professionals decide to study higher-level education while working, allowing for life-long learning.
- Flipped/inverted Classroom, where the reading/listening is done before the lecture and the time with the teacher can be used for practical discussions or more

advanced teaching, which can be further combined with many other techniques. Students usually think it is more work and less learning, but research has demonstrated increased deep-level learning for the same amount of time-on-task (McLean et al., 2016). From a job perspective, it enables a mentality of productive work meetings where the time dedicated to meeting other people is used in an active way, instead of just listening to others.

- Collaborative/team-based learning (Terenzini et al., 2001), encouraging the learner to contribute to the learning of others and to learn from others, is essential in a multidisciplinary sector like Railways where the interaction and overlap between disciplinary areas are inevitable.
- Informal learning, the spontaneous and non-structured learning that occurs in our daily life in different contexts, is very important in a system like Railways where many interactions occur between subsystems that are best exemplified by immersing in the topic in real life.

All of these can be used in the development of courses and modules for modernising railway education and adapting it to current practices.

3 Railway Sector Needs and Expectations

This section analyses the needs and expectations of the railway industry regarding the skills and education of the future workforce. The objective is to find out a number of groups of skills or knowledge that require special attention from higher education institutions.

In the industry surveys companies from the railway sector were asked to state particular skills future employees are supposed to have. This data serves as the basis for the present analysis where we try to confirm the 'stated preferences' from the industry surveys, it is compared to the 'revealed preferences' from the investigated job offers. Since the data from the job offers is way less specific than in the surveys, we grouped the single skills in "skill groups" to facilitate the comparison.

Finally, for each Rail Careers Matrix (RCM) level (European surveys) and for the German survey the five most demanded skills are selected.

3.1 Stated Preferences: Survey Data

The survey consisted on general questions, questions about the skills which rail companies required from the strategic, tactical and operational point of view (see the RCM); and about recently hired graduates and their abilities.

An online survey was carried out between April and September 2021. A database of railway companies was created that included operators, infrastructure managers, transport authorities, international rail companies and more from 25 European

countries. The answer frequency was quite low, 54 companies completed the questionnaire.

A German language survey was also created with questions less specific about the strategic, tactical and operational levels. A database of companies was created, and transport associations were also used to disseminate the questions among their associates. The anonymous online survey was conducted from April to May 2021, receiving 41 complete responses.

The data from the surveys has been split into four parts. There is one part for each of the three Rail Careers Matrix (RCM) levels operational, tactical, and strategic from the Europe-wide survey. The fourth part contains information from the German survey, here no distinction by RCM level has been made. As part of the evaluation of these four different data sets, a score from 1 to 4 (low to high demand) was associated with all different types of companies and all skills. Table 3 shows an example of these scores.

Note that all categories are directly related to a certain area of the rail system, so very general categories such as "Project management" are not present in the survey.

3.2 Revealed Preferences: Data from Job Offers

The data from the surveys is to be compared with data drawn from the investigation of job offers. This is to confirm the validity of the data obtained from the surveys. For gathering the data, 232 job offers from European countries have been gathered and analysed, obtaining data on the stakeholder sector, skills required, specific needs in the form of educational level or area of expertise, etc.

Since the data from the job offers are not as detailed it does not allow for a "skill by skill" comparison. Thus, we introduced skill groups as demonstrated in Table 4. As shown in Table 3, the different skills have been grouped into these, to facilitate the comparison with the data from the investigated job offers.

To determine the most demanded skills among the investigated job offers, each job offer was manually assigned one of the skill groups. In some cases, it was not possible to assign individual offers to a skill group. This was either due to a lack of information in the present data or to the fact that the offers required skills that were not among those investigated in the surveys. Unfortunately, the original information was not accessible anymore, as the job offers had been collected several months prior to the time of the present analysis.

3.3 Comparison Between Stated and Revealed Preferences

In the "European job offers" (all job offers except GER and AUT) (n = 172) 37% of job offers could not be assigned to one of the skill groups above (Table 4). This 37% consisted of 15% requiring Management related skills, 3% requiring System

Table 3 Example for survey evaluation results (Strategic - Europe-wide survey)

Strategic (Europe-wide survey)		Infrastructure manager	Freight transport operator	regulation authority	rolling stock manufacturer	information developer	other administration group	other manufacturing company	Engineering and consultancy company
Railway dynamics	Active steering	2.40	2.71	3.00	2.67	3.00	2.14	1.00	2.58
	Wheel set	1.00	1.00	1.00	2.17	1.00	1.00	1.00	1.00
	Suspension	1.00	1.00	1.00	2.33	1.00	1.00	1.00	1.00
	Wheel-rail interface	1.00	1.00	1.00	2.33	1.00	1.00	1.00	1.00
Traction and braking	Diesel	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00
	Electric	1.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00
	Energy consumption	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Fuel cells	1.00	1.00	1.00	2.17	1.00	1.00	1.00	1.00
	Gas turbine	1.00	1.00	1.00	1.50	1.00	1.00	1.00	1.00
	Magnetic levitation	1.20	1.29	1.25	1.83	1.00	1.00	1.00	1.79
	Traction drives	1.00	1.00	1.00	2.67	1.00	1.00	1.00	1.00
	Braking	1.00	1.00	1.00	2.67	1.00	1.00	1.00	1.00
Signalling	ERTMS	1.80	2.29	2.50	1.67	1.00	2.14	1.50	2.26
	ETCS	1.80	2.43	2.50	2.00	1.00	2.14	1.50	2.63
	Route based signalling	2.20	2.00	1.00	1.00	1.00	1.00	1.00	1.00
	Speed based signalling	1.00	2.14	1.00	1.00	1.00	1.00	1.00	1.00
	Automatic train control	1.00	1.71	1.00	1.00	1.00	1.00	1.00	1.00
	Electromagnetic compatibility	1.00	1.00	1.00	3.00	1.00	1.00	2.50	1.00
	Lighting	1.00	1.00	1.00	1.67	1.00	1.00	1.00	1.00
	Interlocking	2.00	1.71	2.50	1.67	1.00	2.43	1.00	2.16
Externalities	Air pollution	2.00	1.71	2.00	2.17	1.00	1.43	1.00	2.37
	Noise pollution	2.00	2.00	2.00	2.50	1.00	1.43	1.00	2.32
	Other knowledge of transport externalities	2.60	2.00	2.75	2.17	1.00	2.29	1.50	2.58
	Sustainability	2.20	2.43	3.00	1.50	1.00	2.71	2.00	2.74
Costing	CBA (Cost Benefit Analysis)	2.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Infrastructure cost modelling	2.60	1.00	1.00	1.00	1.00	1.00	1.00	2.79
	LCC (Life Cycle Cost)	2.80	2.57	2.50	3.17	1.00	2.00	1.00	2.53
	Railway costing	2.60	3.57	3.00	3.17	2.00	2.29	1.00	2.63
Operation	Distributed power	1.00	1.00	1.00	2.83	1.00	1.00	1.00	1.00
	Freight management	1.00	3.57	1.00	1.00	1.00	1.29	1.00	1.00
	Interoperability	2.60	2.86	2.75	3.00	1.00	3.14	1.00	2.47
	Passenger management	1.00	1.00	2.00	1.00	2.00	1.43	1.00	2.16
	Timetable management	2.40	2.43	2.75	1.00	1.00	1.43	1.00	1.00
Legal	Government regulation	2.80	2.71	3.50	3.00	1.00	3.43	1.50	2.79
	Safety regulations	3.00	3.29	3.75	3.17	1.00	2.71	2.00	2.79
	Transport legal framework	2.40	2.86	3.25	2.33	2.00	2.71	1.50	2.47
Planning	Route assigmnment	2.20	2.43	1.00	1.00	1.00	1.00	1.00	1.00
Car body	Body construction	1.00	1.00	1.00	3.17	1.00	1.00	1.00	1.00
Modelling and data	Demand forecasting	2.20	3.00	2.75	1.00	1.00	2.43	1.00	1.00
	Programming and software development	2.40	1.86	2.50	2.67	4.00	1.71	1.00	2.68
	Transport modelling and simulations	2.40	1.86	1.00	1.00	4.00	1.00	1.00	2.63
	Data analysis	2.60	2.57	2.75	3.17	4.00	2.14	2.50	3.05
Logistics	Logistic technologies and transport chain management	2.40	2.71	2.25	2.17	3.00	2.00	1.00	2.11
	ITS (Intelligent Transport System	2.20	2.29	2.50	3.00	1.00	2.29	1.00	2.74
Track	Track capacity management	2.60	2.14	1.00	1.00	1.00	1.00	1.00	1.00
	Level crossings	2.20	1.00	1.00	1.00	1.00	1.00	1.50	1.00
Safety and security	Security	2.60	2.43	4.00	3.17	2.00	2.14	1.00	2.47
	Safety	2.80	3.29	3.00	3.33	2.00	2.57	1.50	2.79
Reliability and asset control	Availability	1.00	2.29	1.00	1.00	1.00	1.00	1.00	1.00
	Maintenance	1.00	1.00	3.25	3.17	1.00	1.00	2.50	2.37
	Reliability	2.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Remote monitoring	2.40	2.86	1.00	1.00	4.00	1.00	2.50	1.00
	Resource management	2.60	2.86	3.25	2.83	2.00	2.86	1.00	2.95
Auxiliary	Heating and ventilation	1.00	1.00	1.00	2.17	1.00	1.00	1.00	1.00

Table 4 Skill groups

Skill group	Keywords							
Auxiliary	Heating and ventilation							
Car body	Body construction							
Costing	CBA (Cost Benefit Analysis)	Infrastructure costs modelling	LCC (Life Cycle Cost)	Railway costing				
Externalities	Air pollution	Noise pollution	Other knowledge of transport externalities	Sustainability				
Legal	Government regulations	Safety regulation	Transport legal framework					
Logistics	Logistic technologies and transport chain management	ITS (Intelligent Transport System)						
Modelling & Data	Demand forecasting	Programming and software development	Transport modelling and simulations	Data analysis				
Operation	Distributed power	Freight management	Interoperability	Passenger management	Timetable management	Stations		
Planning	Route assignment							
Railway dynamics	Active steering	Wheel set	Wheel-rail interface	Suspension				
Reliability and asset control	Availability	Maintenance	Reliability	Remote monitoring	Resource management			

(continued)

Table 4 (continued)

Skill group	Keywords							
Safety & security	Safety	Security						
Signalling	ERTMS	ETCS	Route based signalling	Speed based signalling	Automatic train control	Interlocking	Electromagnetic compatibility	Lightning
Structures	Bridges	Drainage	Earthworks	Tunnel				
Track	Track	Track capacity management	Level crossing					
Traction & braking	Diesel	Electric	Energy consumption	Fuel cells	Gas turbine	Magnetic levitation	Traction drives	Braking

Engineering skills and 2% requiring Business skills. The remaining 18% simply did not offer enough information.

In the "German job offers" (job offers from GER and AUT) (n = 60) 25% of job offers could not be assigned to one of the skill groups. This 25% consisted of 8% requiring Management related skills, 3% requiring System Engineering skills and 5% requiring Business skills. The remaining 8% did not offer enough information.

The 63%/75% (Europe/GER + AUT) could be assigned one of the skill groups used for the comparison with the data from the survey. To facilitate this, the number of job offers from one company category requiring a certain skill group was divided by the total number of job offers from this company category, resulting in a score between zero and one. This was done for all the above-mentioned sub-datasets (operational, tactical, strategic, and German). Table 5 shows an example.

The skill specific data from the surveys had to be generalised per skill group. For this matter a mean value for each skill group was used. Table 6 shows an example.

The red borders in Table 5 and Table 6 signify the most demanded skills. In the subset strategy of the European survey, the most demanded skills according to the survey are car body, modelling and data, reliability & asset management, track and traction and braking. According to the investigated job offers the most demanded skills in the same subset are externalities, legal, modelling and data, logistics, and safety and security. Since the most demanded skills obtained from the survey overlap in just one case (modelling and data) with the ones obtained from the job offers, we must conclude that the revealed preference does not confirm the data gathered from the surveys. As Table 7 shows, this is also not the case for the other subsets (the overlaps are marked in blue).

The job market analysis has some limitations though. It does not necessarily include the bigger gaps or needs in the railway market, but the jobs that have a higher

Table 5 Example of skill group specific evaluation obtained from job offers

Strategic	Developer/manufacturer of control and safety technology in rail transport	Development/ supply of information in rail transport	Economics company	Engineering/ consulting company	Freight transport company	Infrastructure manager	Manufacturer of rail vehicles or rail vehicle equipment	Other manufacturing company of the railway industry	Passenger transport company	Regulation authority
Auxiliary	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Car body	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5000
Costing	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Externalities	0.0000	0.0000	0.0000	0.0714	0.0000	0.0000	0.0000	0.0000	0.1250	0.0000
Legal	0.0000	0.0000	0.0000	0.0000	0.0000	0.3333	0.0000	0.0000	0.0000	0.0000
Logistics	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1250	0.0000
Modelling & Data	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000
Operation	0.0000	0.0000	0.0000	0.0714	0.0000	0.0000	0.0000	0.0000	0.1250	0.0000
Planning	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Railway dynamics	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Reliability & Asset management	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5000	0.0000	0.0000	0.0000
Safety & Security	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Signalling	0.0000	0.0000	0.0000	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Structures	0.0000	0.0000	0.0000	0.0714	0.0000	0.0000	0.0000	0.0000	0.1250	0.0000
Track	0.0000	0.0000	0.0000	0.2857	0.0000	0.1667	0.0000	0.0000	0.2500	0.0000
Traction & Braking	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 6 Example of Skill group specific evaluation obtained from surveys

Strategic (Europe-wide survey)	Infrastructure manager	Freight transport operator	regulation authority	rolling stock manufacturer	information developer	other administration group	other manufacturing company	Engineering and consultancy company
Railway dynamics	1.35	1.43	1.50	2.38	1.50	1.29	1.00	1.40
Traction and braking	1.03	1.04	1.03	2.11	1.00	1.00	1.00	1.10
Signalling	1.48	1.79	1.56	1.63	1.00	1.46	1.31	1.51
Externalities	2.20	2.04	2.44	2.09	1.00	1.97	1.38	2.50
Costing	2.70	2.04	1.88	2.09	1.25	1.57	1.00	2.24
Operation	1.60	2.17	1.90	1.77	1.20	1.66	1.00	1.53
Legal	2.73	2.95	3.50	2.83	1.33	2.95	1.67	2.68
Planning	2.20	2.43	1.00	1.00	1.00	1.00	1.00	1.00
Car body	1.00	1.00	1.00	3.17	1.00	1.00	1.00	1.00
Modelling and data	2.40	2.32	2.25	1.96	3.25	1.82	1.38	2.34
Logistics	2.30	2.50	2.38	2.59	2.00	2.15	1.00	2.43
Track	2.40	1.57	1.00	1.00	1.00	1.00	1.25	1.00
Safety and security	2.70	2.86	3.50	3.25	2.00	2.36	1.25	2.63
Reliability and asset control	1.96	2.00	1.90	1.80	1.80	1.37	1.60	1.66
Auxiliary	1.00	1.00	1.00	2.17	1.00	1.00	1.00	1.00

Table 7 Overlap of top 5 skills between surveys and job offers

	top five demanded skills									
subset	survey					job offers				
European strategic	Externalities	Legal	Modelling and data	Logistics	Safety and security	Car body	Modelling & Data	Reliability & Asset management	Track	Traction & Braking
European tactical	Costing	Legal	Logistics	Safety and security	Reliability and asset management	Modelling & Data	Planning	Signalling	Track	Traction & Braking
European operational	Signalling	Legal	Modelling and data	Safety and security	Reliability and asset management	Operation	Planning	Reliability & Asset management	Track	Traction & Braking
Germany + Austria	Costing	Operation	Legal	Modelling and data	Safety and security	Car body	Operation	Planning	Signalling	Traction & Braking

density (i.e. there are lots of that specific category employed in the sector) or have bigger turnover (people change jobs more often in that sector). Additionally, the sampling has been done with a specific keyword in mind, "railway", which might also limit the results obtained from the job offers, e.g., won't cover consultant companies working in broader infrastructure-related projects, or component suppliers that provide specific components in the railway system. Furthermore, each job offer ($n = 170 + 60$) covers only one position, while for the surveys with a much smaller n, each one answers for all the possible job categories they have been asked for directly targeting skill and knowledge gaps.

Because of this, we believe that the data from the surveys are a more reliable source, as it is directly targeting the explicit gaps in the industry. The conclusion is that the relevant top-demanded skill groups can be obtained from the survey-based top 5 evaluation.

Table 8 Most demanded skill groups for each subset

subset	top five demanded skills				
European strategic	Externalities	Logistics	Modelling and data	Legal	Safety and security
European tactical	Reliability and asset management	Logistics	Costing	Legal	Safety and security
European operational	Reliability and asset management	Signalling	Modelling and data	Legal	Safety and security
Germany	Costing	Operation	Modelling and data	Legal	Safety and security

The relevant top five skill groups for each of the subsets can be found in Table 8. The colours signify how many times the particular skill is mentioned among the subsets. The data are essentially identical to the data presented on the left-hand side of Table 7.

Dealing with data from surveys always implies some uncertainty about whether the responses given are true and valid. To deal with the stated preferences, we tried to confirm the findings from the survey by using the job offers investigated. Unfortunately, this was not possible. The rather low number of job offers, the non-systematic approach in their acquirement as well as the manual classification into skill groups introduced a lot of uncertainty concerning the job offers.

4 Parallel Sectorial Experiences

The objective of this section is to see if there have been any similar activities performed in similar sectors like the aeronautical or vehicle engineering, and how the higher education institutions and industry stakeholders have collaborated in order to develop the higher education curricula in a way that meets the needs for a certain talent pool. In the end and due to the wide array of industries, programmes, etc. the work was concentrated on identifying best and worst practices in academia related to teaching skills.

4.1 Analysis

The main driver is a student standpoint for the effective and efficient learning process that is covered using advanced teaching methods. In the following tables is represented the proportion of pure lectures (Table 9) and exercise sessions (Table 10) in the university activities for the different studied universities.

The number of theoretical hours is particularly high at some of the universities, which hints to outdated teaching praxis of hearing and repeating. Traditionally, at engineering universities, students gain a wide ranged basis of different engineering pillars. Positive about that is that they can understand a wider range of problems. But a negative aspect is that the amount of needed knowledge increases. In conclusion, it seems necessary to weigh the amount of basic engineering knowledge and build up new emerging knowledge, introducing new teaching activities that focus on student learning and not necessarily in lecturing.

All studied universities are using, in some cases, advanced teaching activities but they are mostly on a voluntary basis and depend strongly on the personal engagement of university professors. This differs between the project partner countries. The analysis of parallel experiences shows that at some project partner universities, the proportion of exercises in the curriculum is more than 30%. Table 2 is a comparative analysis of exercise hours and percentages among partner universities which include exercises held in a lecture room or/and laboratory. In addition, some project partner

Table 9 Comparative analysis of theoretical teaching hours and percentage

Universities	Study program	Lecture (hours)	Lecture (%)
UNIZG	Railway study program	345	54
	Aeronautical study program	120	66
KTH	Railway Engineering		49
	Vehicle Engineering (Railway track)		46
	Aerospace Engineering		41
UNIZA	Railway transport	106.75	40.47
	Railway structures	129	44.29
	Forwarding and logistics	114.25	43.32
DICEA	Aeronautical and maritime	310	63
	Traffic and logistics	310	63
	Railway	310	63
UMA	Intelligent systems in Energy and Transportation	332	57
	Industrial Engineering	538.5	66
	Mechatronics	274.5	73
TH WILDAU	Transportation System Engineering	63	50.81
	Logistics	57	45.97

Table 10 Comparative analysis of exercises hours and percentage

Partner universities	Study program	Exercises (hours)	Exercises (%)
UNIZG	Railway study program	190	31
	Aeronautical study program	57	31
KTH	Railway Engineering		47
	Vehicle Engineering (Railway track)		53
	Aerospace Engineering		56
UNIZA	Railway transport	157	59.52
	Railway structures	162.25	55.71
	Forwarding and logistics	149.50	56.58
DICEA	Aeronautical and maritime	182	37
	Traffic and logistics	182	37
	Railway	182	37
UMA	Intelligent systems in Energy and Transportation	215	37
	Industrial Engineering	190.50	23
	Mechatronics	89.50	24
TH WILDAU	Transportation System Engineering	44	37.10
	Logistics	54	43.55

universities offer practice-oriented teaching approaches including e. g. the use of laboratories or the integration of internship semesters.

4.2 Highlights

Based on the thorough investigation of what the common approaches are in these parallel programmes, we can highlight the following activities that could be considered in the rail sector and education, differentiating between bachelor and master:

Bachelor level (3 years—180 ECTS)

1. Limit the obligatory basic engineering courses within the first year (two semesters). This way, basic engineering is taught in the first year of study only, and the next two years are reserved for more specific railway courses.
2. Introducing obligatory course about system engineering. At its root of existence, the railway is a system-oriented engineering study. So, system engineering is key and basic knowledge.
3. Introducing laboratories in the curriculum as standalone courses with close didactic integration into the curriculum. Different Higher Education Institutions (HEIs) introduce laboratories in their curriculum. According to positive parallel

experience, for example, UNIZA, laboratories as the standalone course offer students a better understanding and focus on learning topics.

4. Introducing practical skills seminar during the study period. In today's society, soft skills are crucial for understanding work and communication in the railway system. Therefore, these skills need to be implemented in various courses during the study period.
5. Teaching some courses in a foreign language (for example English language, German language, etc.) There is a big difference in foreign language knowledge between European countries. To increase foreign language knowledge, it will be wise that identical courses at different higher education institutions (HEIs), full or partial, be offered to students.
6. Establish elective modules that are focused on concrete knowledge (for example automotive industry, transport services, railway operation, and traffic planning) The railway system is a huge area of knowledge and expertise. In that sense, it will be feasible to offer students different modules. By choosing courses that fit their interests, the students are much more focused on their studies.
7. Invite external professors and professionals from the industry with a combination of lecture plus panel discussion. Students should be allowed to discuss similar or the same topics with external professors and/or practitioners. In this way, they gain experience in understanding the same or similar topics from different points of view.
8. Set up seminars in which students solve practical problems in groups (if possible, with industry partners that formulate the problem). To get better acquainted with the practice or the real state of the industry, various seminars with practice can be introduced that are concentrated on real problem-solving.
9. Include internships to enable the students to gain practical experience during their studies as the bachelor's degree is the first professional qualification and practical experience is therefore needed The internship should be able to be provided to students during their studies. In this way, they will personally experience what it means to work in practice.
10. Write Bachelor thesis with/at industry partners. This approach enables a detailed acquaintance with the detection of the problem and its solution in the real environment.

Master level (2 years – 120 ECTS)

1. Only the first semester with obligatory advanced engineering courses. This way, only advanced engineering courses are taught in the first semester of study, and the next semesters are reserved for advanced railway courses.
2. Introducing obligatory courses about system-specific useable, general scientific research methods that can be applied in railway engineering (for example operational research methods, game theory, e.g.) Today's engineering is based on different types of research methods e.g., in optimization. So that students can understand complex system relationships and system handling, e.g., in optimization it is recommended to introduce a specific optimization course.

3. Introducing laboratories in the curriculum as standalone courses with close didactic integration into the curriculum. Different HEIs introduce laboratories in their curriculum. According to positive parallel experience, for example, UNIZA, laboratories as the standalone course offer students a better understanding and focus on learning topics.
4. Introducing seminars in the curriculum as standalone courses (creating new products/services, benchmarking, debates)—strong connection with industry. Different HEIs introduce seminars in their curriculum very often as a part of the course. Seminars as the standalone course (with close didactic integration into the overall curriculum) offer students a better understanding and focus on learning topics. But also working in and team and communicating with the industry.
5. Introducing soft skills seminar during the study period. The future master engineer is expected to communicate well (in speech and writing), allocate resources and manage teams or projects. These skills are soft skills and their training during the study period is essential.
6. A significant part of courses, there is an emphasis on European or international topics, such as ECTS or INCOTERMS, to teach English. There is a big difference in English language knowledge between European countries. To increase English language knowledge, it will be wise that identical courses, full or partially, be offered to students at the master level of study. This also will increase student mobility opportunities and the exchange of knowledge.
7. Introducing elective courses for different specific research topics (for example intermodal transport, timetabling, fleet management, marketing of services, travel behaviour, …) Although students are concentrated on studying the railway system, each of them has some personal preferences or subjects where he sees himself in the work environment, so it is necessary to offer different elective courses dealing with specific areas of railway engineering.
8. Invite external professors from different Universities/Faculties. Students should be allowed to discuss similar or the same topics with external professors. In this way, they gain experience in understanding the same or similar topics from different points of view.
9. Invite professionals from the industry with a combination of lectures and panel discussions. Students should be allowed to discuss similar or the same topics with professionals. In this way, they gain experience in understanding the same or similar topics from different points of view.
10. Organize regular technical visits (2–3 days per semester). For students to gain practical insight into theoretical knowledge, technical visits are organized to various industrial partners.
11. Obligatory internship (at least 3 Months) during the study. The internship should be able to be provided to students during their studies. In this way, they will personally experience what it means to work in practice.
12. Connect study programs with similar European union universities/faculties for establishing mobility among partners (professors and students). This way,

students will be able to expand their knowledge beyond the context of their own country and certainly better understand the single railway area.

13. Organize once per whole study program student competition (Hackathons or similar events). Today's industry is a highly competitive area, so the introduction of competitions allows students to cope in such an environment.
14. Master thesis fully connects with industry partners. Preparation, research, and presentation of master's theses should be fully related to the industry. This creates a win–win situation for all stakeholders involved.

All these points are either current practices in European universities, or suggestions raised during the discussions, and they create a critical size of experiential learning and industrial collaboration to promote the engagement of stakeholders with future employees earlier in the process.

5 Mapping Out Gaps Between Stakeholder Expectations and University Provision

This section will gather all the information in the previous sections and propose a good representation and visualisation of the correlation between the existing education and the industry needs, tailored for the prospective public (universities and companies). Cross-analysing the demands of the railway industry with those of the universities will help find development needs, but also generate material that can be used for project outreach with high visual impact.

5.1 Finding Gaps and Mismatches in the RCM

The gaps found in the industry analysis (Table 8) are not necessarily explicitly related to the RCM Levels and Domains. To understand where the needs are coming from, each RCM category description has been analysed, searching for references to the actual needs in Table 8. The result is depicted in Fig. 4, Fig. 5, and Fig. 6, where the explicit mention of the gap is marked with "Yes" and an implicit or more vague mention is marked with "not always".

For the industry needs coming from the German speaking survey, there is no possibility of performing this analysis because of the lack of differentiation in the Levels; from the overlap in these results, it is already evident that there are different needs in different levels, which won't be showcased for these survey results.

A more detailed analysis shows that:

- Reliability and asset management is a need that appears over all the different job domains, making it a low hanging fruit for a cross-disciplinary improvement.
- Modelling and data are not mentioned in many places in the RCM but is considered a big need from industry. This should be reviewed.

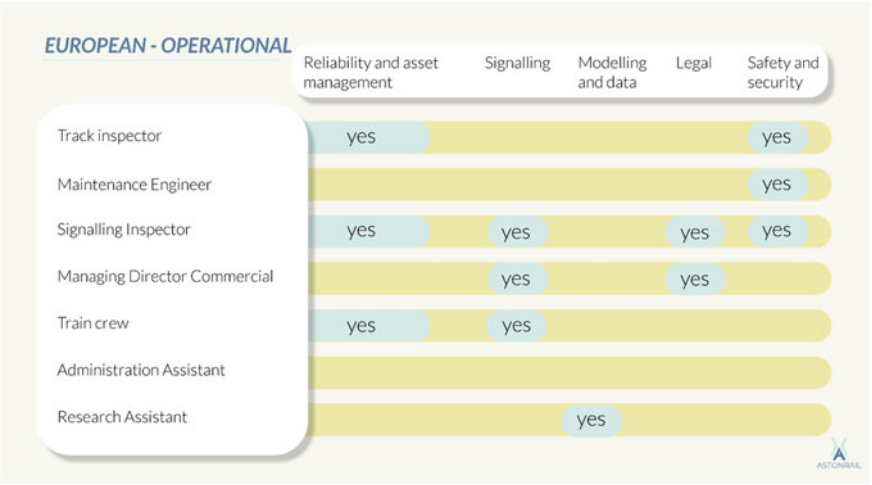

Fig. 4 Mentions of Industry needs in the RCM Operational level

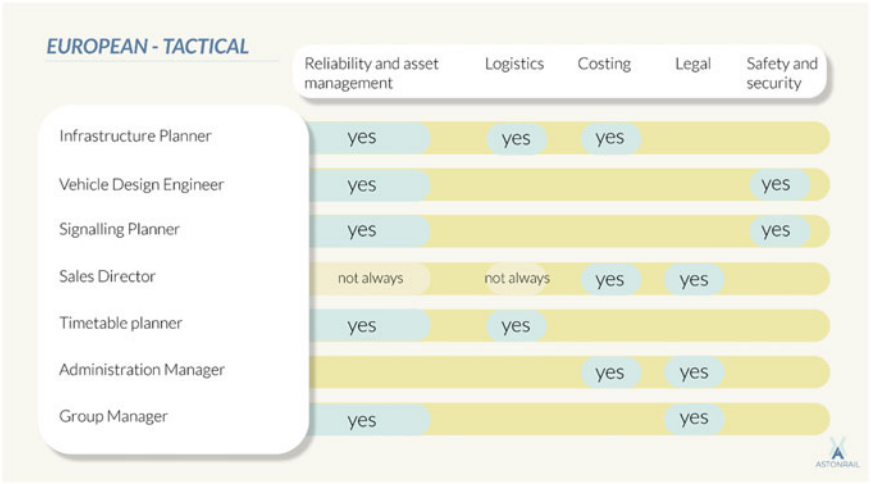

Fig. 5 Mentions of Industry needs in the RCM Tactical level

- Safety and security are mentioned in different job descriptions in the different level categories, so its consistency should be reviewed—having gaps at different category levels for different job descriptions should be double-checked.
- Legal is a category that covers Government regulations, Safety regulations and Transport legal framework, so the needs have a higher level but are system specific, cascading into every subsystem and applicable to every level of the RCM. A more specific analysis is needed so that the actual specific needs are understood and addressed in educational programs.

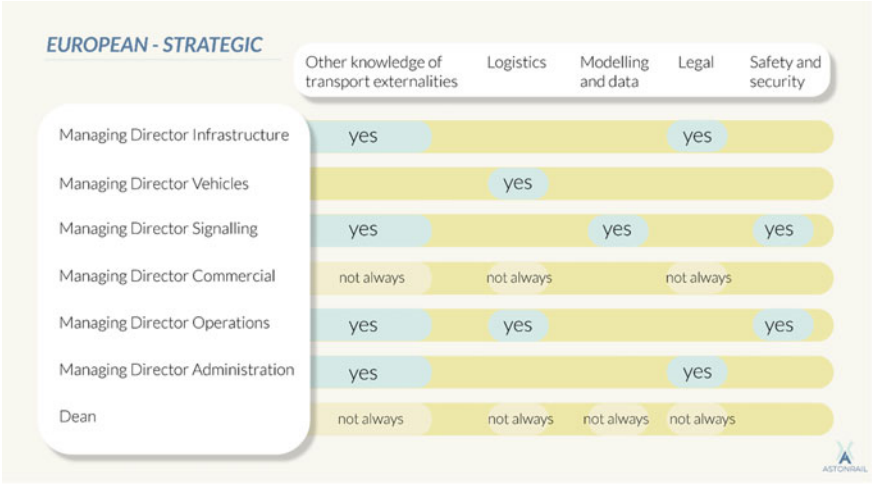

Fig. 6 Mentions of Industry needs in the RCM Strategic level

For a better coupling of the results from different work packages, a more systematic cross-disciplinary surveying should be defined. A single survey with a unique categorisation of paths (both study and career paths) that addresses both the Domain, and the Level in the RCM should be developed.

6 Conclusions

The main output of this work is a depiction of the gaps existing in the university provision, the expectations and desires of industrial partners, and an analysis of the suitability of the Rail Careers Matrix for highlighting the needs and expectations of the industry while coupling it to the educational provisions. Putting all this information together has showcased the possibilities and limitations of linking higher education paths and outcomes with specific job offers or needs, and in doing so, study path and permeability have been defined.

- Study path is defined by its endpoint, the final academic title, and covers the yearly academic components from the first bachelor course until that end. Even if defined by the result, an individual study path is already defined from start to end, so different study paths can lead to the same job position.
- Permeability defines how many different study paths reach a certain outcome, i.e., how easy it is for students of different backgrounds to arrive at that academic title.

Defining a systematic scale, a more thorough picture has been depicted, showing some study paths that are narrow (Mechanical Engineering, Infrastructure Engineering as well as Material Science) and others that are broader (Transport and Logistics, Energy & Environmental Studies and Transport Systems Engineering).

From the job market and stakeholder analyses, a thorough consolidation job has been carried out to highlight the top five skill groups that are needed in the railway industry. There is inherent uncertainty when dealing with data from surveys, so the stated preferences were compared with the revealed preferences from the job offers, with lukewarm results.

A systematic study of different sectors has also been performed, with a substantial amount of information coming from different university environments. A complete list of best practices for addressing student deep learning and engagement has been assembled, which is useful information for upcoming work packages. There is sadly no validation of these proposals when it comes to their positive or negative outcomes in coupling education provision and the jobs market in their respective sectors. The output of this study is still a very powerful analysis of academic practices in Europe and the final discussion will enable proposals in continuation work.

Finally, all the previous work has been crystallised in a visual representation of the Gaps and Mismatches both from the RCM and Career Paths point of view, highlighting those skills and educational areas that need an increased amount of talent in the railway sector. Some of the main conclusions are the need to strengthen Reliability and asset management and integrate Modelling and data in the study paths, as they are considered a big need from the industry. Additionally, Safety and security and Legal should be reviewed, as their high-level needs have subsystem-specific applications. A more specific analysis is needed so that the actual specific needs are understood and addressed in educational programs.

Acknowledgements We are grateful for the collaboration of the ASTONRail project researchers involved in the gathering of educational information, surveying stakeholders, and mapping experiences in parallel sectors: Anne-Katrin Osdoba and Martin Lehnert (Wildau University, Germany); Stefano Ricci and Arbra Bardhi (Sapienza University, Italy); Anna Dolinayová, Eva Nedeliaková and Igor Domeny (University of Zilina, Slovakia); Marin Marinov, Reem Hadeed and Prachiti Prashant Shinde (Aston University, the United Kingdom); Armando Carrillo Zanuy (EURNEX, Germany).

References

Ahern, A. (2017). SKILLFUL D2.1 Best practices on current and emerging training schemes, methodologies and tools in the transport sector and mapping to future training requirements and scenarios.

ARM. (2023). Rail & Infrastructure Labour Market Report - Talent Insights for Summer 2023. https://www.arm.co.uk/rail-infrastructure-labour-market-report-talent-insights-for-summer-2023/ (accessed September 1, 2023).

McLean, S., Attardi, S. M., Faden, L., & Goldszmidt, M. (2016, March). Flipped classrooms and student learning: Not just surface gains. *Advances in Physiology Education, 40*(1), 47–55. https://doi.org/10.1152/advan.00098.2015

Nikou, S., & Maslov, I. (2021, January). An analysis of students' perspectives on e-learning participation—the case of COVID-19 pandemic. *The International Journal of Information and Learning Technology, 38*(3), 299–315. https://doi.org/10.1108/IJILT-12-2020-0220

Railway Talents. (2018). Pathways to a career in Rail. *Railtalent*. https://railtalent.org/pathways/ (accessed May 10, 2022).

Shepherd, A. (2022, November 9). Addressing resource challenges in the rail industry. *Infrastructure Magazine*. https://infrastructuremagazine.com.au/2022/11/10/addressing-resource-challenges-in-the-rail-industry/ (accessed September 1, 2023).

Smith, K. (2018). Recruiting the next generation of railway professionals. *International Railway Journal*. https://www.railjournal.com/in_depth/recruiting-the-next-generation/ (accessed September1, 2023).

Terenzini, P. T., Cabrera, A. F., Colbeck, C. L., Parente, J. M., & Bjorklund, S. A. (2001). Collaborative learning vs. lecture/discussion: Students' reported learning gains. *Journal of Engineering Education, 90*(1), 123–130. https://doi.org/10.1002/j.2168-9830.2001.tb00579.x