Rail higher education in Europe: current situation analysis for future developments

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Summary

The paper aims at describing the activities developed within the project ASTONRAIL (Advanced approaches and practices for rail training and education to innovate Rail study programmes & Improve rail higher education provision), funded by ERASMUS+ Programme. The project target is to provide a portfolio of new rail skills development strategies, approaches and professional practices in order to strengthen and modernize Europe's current rail higher education system.

Introduction

The railway transport is one of the fastest growing industrial sector in the world. Currently, there is a pressing need to develop and maintain a trained rail workforce to ensure the industry's long-term viability [1]. Qualified, extended and updated training plans, programs and courses are tools to develop and maintain a skilled rail staff. The first purpose of this paper is to depict an overview of the current study paths in rail higher education in Europe and a reflection of an intensive study programme. In the digital age, the railway is transnational and dynamic, thus necessitating a skilled workforce capable of mastering new technologies, ensuring and facilitating the effective implementation of innovations and effectively managing railway system complexity. In this context, in order to create and retain a workforce that can respond appropriately to new technological developments and innovations, broader economic changes and the complexities of local markets, it is necessary to establish multi-national, multi-cultural and multi-sectorial joint ventures. Their goals are to establish contacts, promote innovation, facilitate implementation and ensure the fullest open exchange of high quality education and training practices at operational, tactical and strategic level. Recently, emerged some challenges in developing an e-learning portfolio, spanning from technologies to cost/benefits aspects, as perceived by training providers [2].

1. Structured analysis on existing study programs on railways

ASTONRAIL's top horizontal and sectorial priority is to close gaps and mismatches between industry requirements, expectations and current higher education offerings for rail knowledge and skills

development. In order to conduct the study, the data collection started from extensive surveys carried out as part of past EU funded projects, such as EURNEX [3], TUNRail [4], SKILLRAIL [5] and RIFLE [6], which comprehensively covered over 70 Higher Education Institutions (HEI) throughout Europe and beyond. Important potential benefits emerged in past studies from the interaction of universities and industries, where United States showed a better interaction with industry than EU, as presented in [7]. On the other side, some problems may arise and create difficulties in the alignment of curricula to industry's needs, as exposed in [8].

The collection of information about existing study programs on railways involved universities offering relevant courses by combining information from many sources, such as previous projects, ASTONRAIL partners, other academic alliances, websites and so on. The next step was an online survey across relevant academic websites to learn more about each course. The combination of data from this survey and the preliminary database represent an articulated database including general information on entire higher education courses and rail-related modules, such as full courses, short courses, modules of a larger course, with a significant amount of rail subjects. The structure of the database allows a significant amount of queries about the description of the content of the courses, as well as the contacts information used to increase and homogenise the level of knowledge within the ASTONRAIL project to proceed towards its fine-tuning. The use of European Qualifications Framework (EQF) and the European Credit Transfer and accumulation System (ECTS) for the description of the level of qualification and the credits count of each course necessary and useful for comparative purposes. The choice to include in the database extra-European universities, with the aim to widen the pool and gaining insights of different programmes as well as the inclusion of short courses, difficult to classify in EQF and by ECTS led to some inconsistency in the quantification of the teaching activities (e.g. frontal hours). The preliminary database consists of 311 confirmed courses, from 190 different institutions. For each course, the defined fields are the following: university/organization; department/institute; course; provider; country; city/state/region; active (yes/no); EQF level; language; ECTS on rail; contacts (e-mail and website). The questionnaire to proceed with the data collection included three sections: 1) confirmation of information in the preliminary database, 2) basic course information (in case of detected discrepancies in the preliminary database), 3) necessary integrative information.

The data acquired, presented and processed in a user-friendly and manageable shape, after standardization and consolidation of the educational supplies in the railway sector by a visual guide targeting prospective students [9].

The primary program categories give the user a broad idea about the contents covered in the programs; synthetically reported to the following engineering (mechanical, environmental, energy, civil, electrical, logistics, vehicle, transport, railway) and rail economy categories (economics, marketing, regulation & framework).

The respective programs classification follows the qualification framework of the Bologna process: Bachelors (EQF = 5), Masters (EQF = 6) and Doctors (EQF = 7). Moreover, the duration of the programs helps to classify them, fitting into the introduced framework: Bachelor (3-4 years), Integrated (5 years), Master (1-3 years), Post graduate (≤1 year), Advanced / Post-master (1 year) and PhD (3-4 years).

The most complex point to address is the amount of railway specific education in each program. The adopted solution was to use a 4-levels scale, where the programs categories are according to the amount of railway specific courses (credits) they encompass, as follows:

1) Program: ≥ 50% of the program rail focused;
2) Module: 20% - 50 % of the credits rail focused;
3) Course: <20% of the credits rail focused;
4) None: no railway specific courses.

A railway overview picture (Figure 1) provides with a comprehensive visualization of the various railway-connected applications and respective disciplines involved. The aim is to facilitate the connection from the concrete real-world application to the conceptual fields of study.

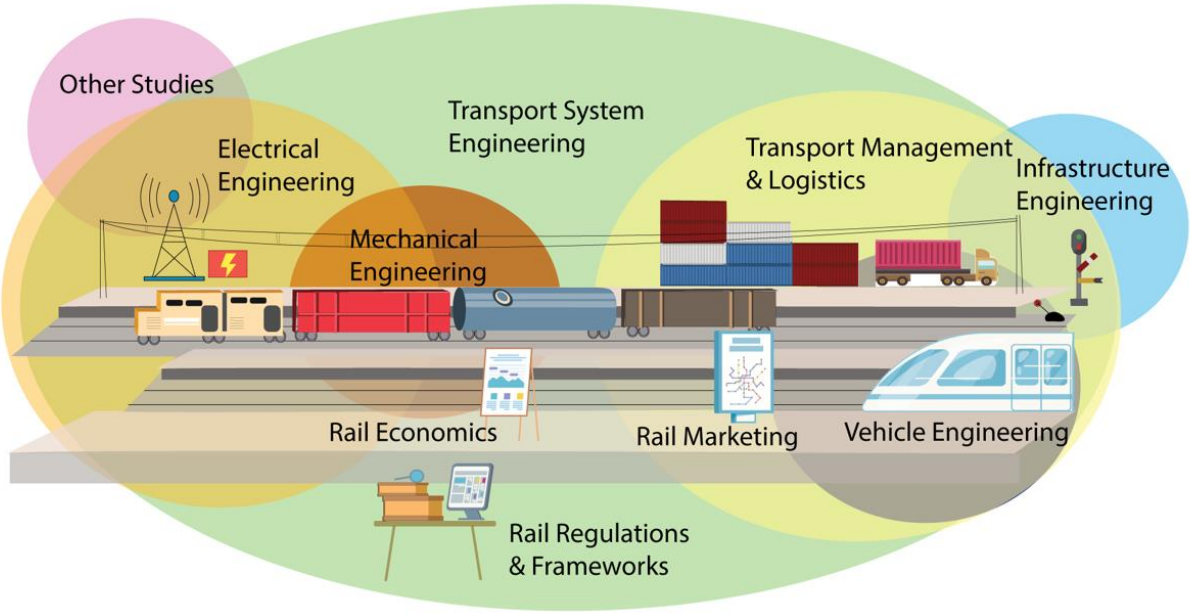

Figure 1: Conceptual visualization of railway disciplines

The result is a comprehensive database of 311 rail related study programs in Europe combined with a visualization concept. These results are ready for the integration into a website for prospective students to facilitate information and orientation for their study choices. The current dataset research clearly demonstrated the traditional understanding of railways still existing today, with civil and transport engineering accounting for more than 50 % of programs and a single program in the field of environmental engineering. Despite the extension and the accuracy in building the database, some residual biases could anyway affect its completeness, though not diminishing its relevancy for the online handbook, under development within the ASTONRAIL project, which will also include the overview of rail related study programs in Europe.

2. Railway sector needs and expectations

Currently, the rail transport market is evolving in all areas: strategic, technical, technological, operational, digital, telematics, informatics, etc. Therefore, the railway industry, represented by manufacturers of rolling stock, signalling, interlocking and information-related equipment, Infrastructure Managers (IM), freight and passengers Railway Undertakings (RU) needs rail staff with new skills, competences and knowledge about advanced technologies. Higher education institutions specialising in rail related subjects must respond to these needs properly. Consequently, it is essential to gain a deeper comprehension of their global and specific expectations to identify gaps and discrepancies between them and the current rail higher education system.

Therefore, the ASTONRAIL project organized a survey dedicated to identify the industry expectations, based on an online questionnaire in English, later integrated with a parallel independent survey developed in Germany in German, focused on staff with engineering background.

The English ASTONRAIL survey initially involved 67 answers from 54 companies worldwide (focus Europe), categories are distributed as in Table 1 (multiple choices were possible). The number of involved companies is not representative for the entire railway industry but enables to draw preliminary conclusions.

Table 1: Categories of rail companies participating in the EU-wide survey

Category	Number of answers
Engineering and consultancy	19
Freight rail undertaking	7
Other administration group	7
Rolling stock manufacturer	6
Regulation authority	5
Infrastructure manager	5
Economics	3
Other manufacturer	2
Information developer	1
Not filled	12
TOTAL	**67**

The education level of the involved staff was very variable: e.g., infrastructure managers and freight operators have 75% -100% employees with high school education level, meanwhile transport authorities and consultancy companies have 75% - 100% employees with Master's degrees.

Nonetheless, when rail companies hire new employees, the preferred degrees (about 35%) are those focused on rail transport and railway engineering (Figure 2).

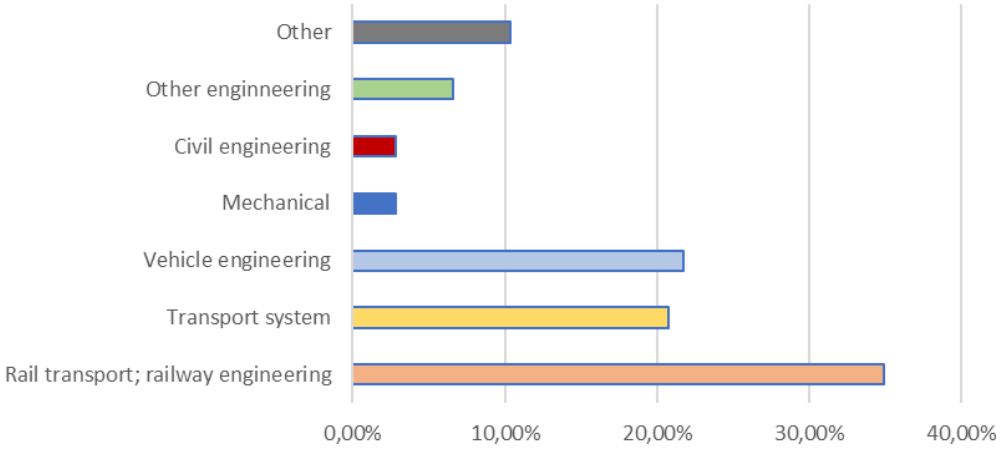

Figure 2: Preferred degree when hiring new employees

Many rail companies stated that demand for skilled workforce exceed supply. Therefore, the majority of them (56 %) regularly provide professional internships for university students during their studies. The need of previously skilled persons emerge also by the fact that only 25% of companies do not require explicitly any previous experience when hiring staff (Figure 3).

Moreover, from the survey emerged that many companies require intensive after graduation training before start working: 19% in any case, 58% depending on the education background of the new employees. The distribution of the staff across the various education task levels (Figure 4) was also variable by the typology of company. Over 50% of employees are working in:

- Operational tasks at IM and freight RU;
- Tactical tasks at consultancy companies;
- Strategic tasks at transport authorities and administrations.

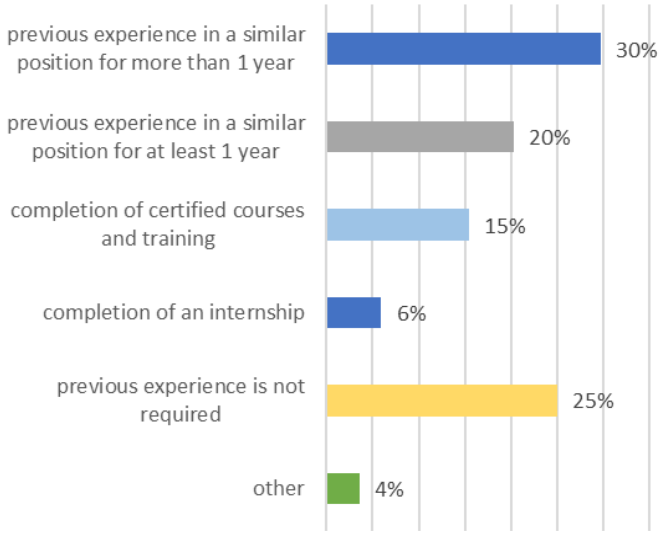

Figure 3: Required previous experiences for newly hired employees

The second part of the questionnaire focused on the detailed skills required by companies within the strategic, tactical and operational tasks. The assignment of judgements weights was by values spanning from indispensable to unnecessary. Table 2 shows an example of the most valued skills from Infrastructure Managers viewpoint.

Table 2: Skills in Strategic, Tactical and Operational tasks required by an IM

Skills	Strategic (13)	Tactical (22)	Operational (11)
Bridges		√	√
Cost Benefit Analysis	√		
Costing	√	√	
Data analysis	√		
Drainage			√
Earthworks		√	√
Electric		√	√
ETCS		√	
Government regulation	√	√	
Infrastructure cost modeling	√	√	
Interoperability	√	√	
Level crossings			√
Life Cycle Costs	√		

Logistics and transport chains		√	
Maintenance		√	√
Reliability	√	√	
Resources management	√	√	
Route assignment		√	
Route based signaling		√	√
Safety	√	√	√
Security	√	√	√
Stations		√	√
Timetable management		√	
Track		√	
Track capacity management	√	√	
Transport externalities	√		
Transport legal frameworks		√	
Tunnels		√	√

Soft abilities, skillsets to work in teams and other attitudes of graduates were under investigation in the third part of the questionnaire.

Moreover, 54% of respondent companies estimated strong or more the complex problem solving skills of newly hired graduates (Figure 4) and 77% of them estimated strong or more their team-working skills (Figure 5). Moreover, 58% of newly hired graduates have capabilities to work in an international context.

The parallel survey carried out in Germany involved 41 participants distributed to the participant categories as shown in Table 4 (multiple choices where possible). The number of participants is not representative for the entire railway industry in Germany. Nevertheless, the conclusions can be anyway useful for the modernization of rail higher education.

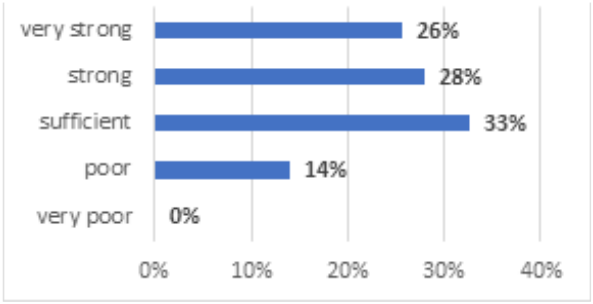

Figure 4: Detected graduates' skills for complex problems solving

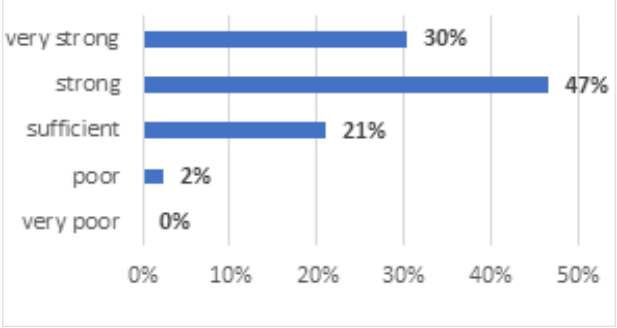

Figure 5: Detected graduates' skills for team working

Table 4: Categories of rail companies participating in the German survey

Category	Number of answers
Infrastructure operator	2
Passenger transport company	7
Freight transport company	5
Regulation authority	0
Other administrative unit (national and international organization)	4
Manufacturer of rail vehicles or rail vehicle equipment	7
Other manufacturing company of the railway industry	6
Developer/manufacturer of control and safety technology in rail transport	3
Development/supply of information in rail transport	2
Engineering/consulting company	16
TOTAL	**52**

When recruiting engineers, the large majority (68%) of the participants preferred a degree in transportation system engineering / transport engineering, followed by mechanical engineering (44%) and industrial engineering (37%) (Figure 6).

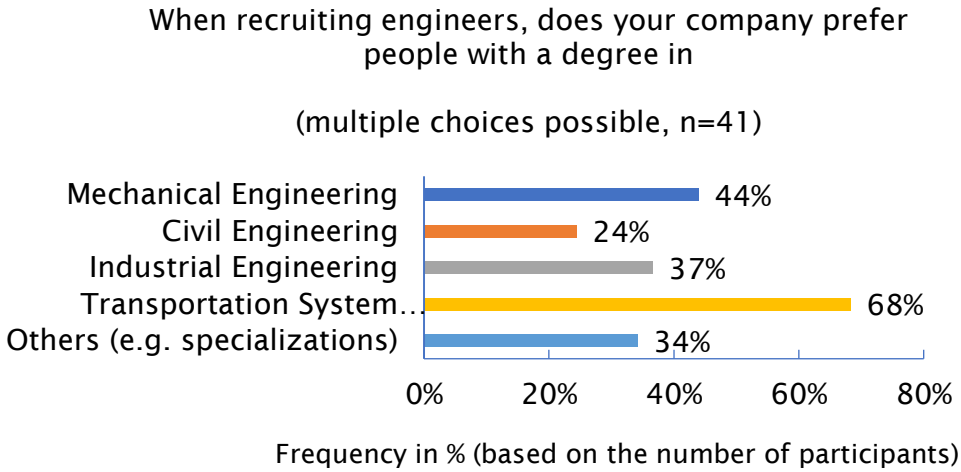

Figure 6: preferred study courses by recruiting companies

Moreover, in the additional free text options, the companies indicated frequently as desired skills the fields of electronics, computer sciences and telematics. Differently from the results of the EU-wide ASTONRAIL survey, the national German context highlights that 39% of companies answered that the abilities of newly enrolled graduates to work in international contexts are insufficient, meanwhile 32% considered them sufficient. Further, 29% of the participants said that skills for working in international contexts are not necessary.

From the German survey also resulted that specialized and practical knowledge of graduates are very important for the employment in the railway industry and needs improvements. Therefore, integrating more

rail relevant teaching contents, ensuring practical contents in courses and implementing internships to gain practical experience should be a priority and would require further investigation when improving rail higher education.

Indeed the combination of the results of the EU-wide and German surveys highlights that the graduation degree and the connected skills is a very important parameter when recruiting new employees. It confirms the preference of transportation system / transport engineering for infrastructure managers, regulation authorities and engineering consultancy.

Moreover, in this global survey feedback, it emerges that in the last years a good number of companies (28%) participated to dual study courses with higher education institutions and considered the relevance of skills to work in an international environment (46%).

An interesting additional finding is companies require skills to work in an international context (almost 46%) but a parallel analysis of job offers shows that the railway sector is still quite locally organized. Finally, foreign linguistic skills are highly appreciated but almost 80% of recruiters are satisfied with the linguistic level of the new employees.

3. Study paths at the different institutions

In this section it is studied how different higher education institutions in Europe deal with the railway systems knowledge in different subsystems and how they eventually link to the different professional levels. The reference is the so-called Rail Careers Matrix (RCM) [10].

Figure 7 highlights the study paths and consists of the available Bachelor programmes (columns) and the available Master programmes (rows). A number 1 in a cell indicates that the concerned Bachelor program allows for unrestricted access to the respective Master program. In case of absence of direct access form Bachelors to Masters, the cell is blank. The study paths are in accordance with the railway overview picture introduced in Figure 1. An example of study paths matrix for KTH Stockholm is in Figure 8.

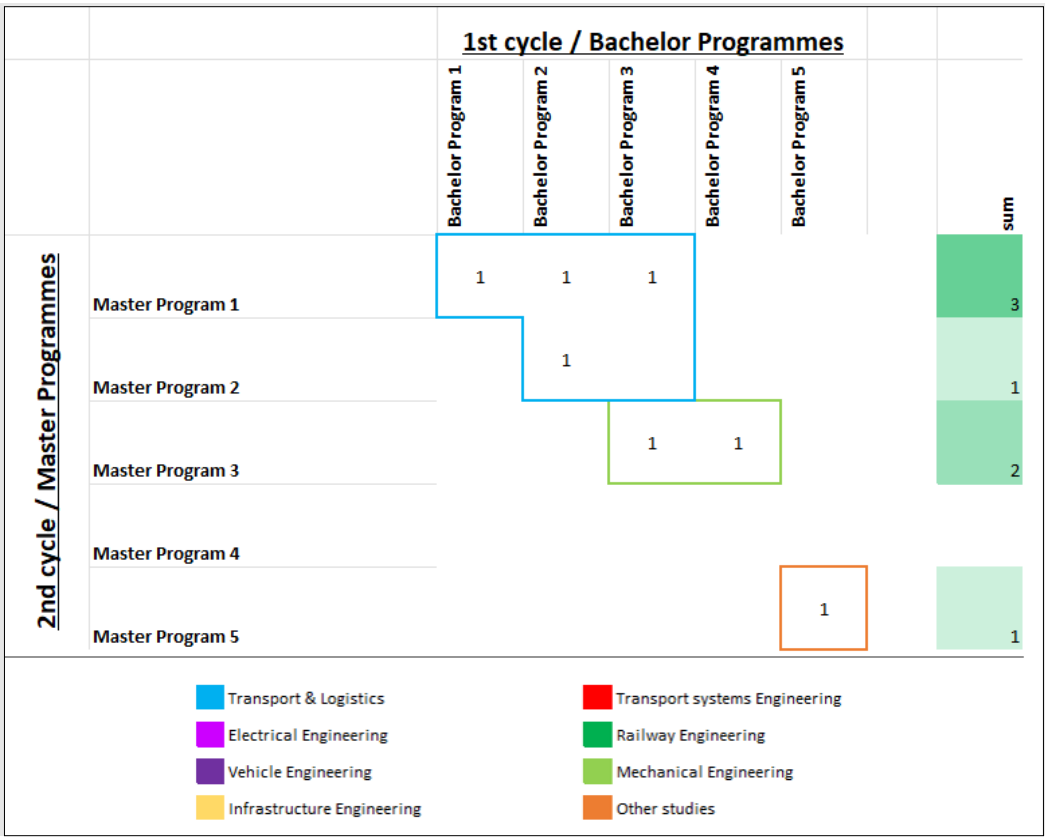

Figure 7: structure of a rail related study paths matrix

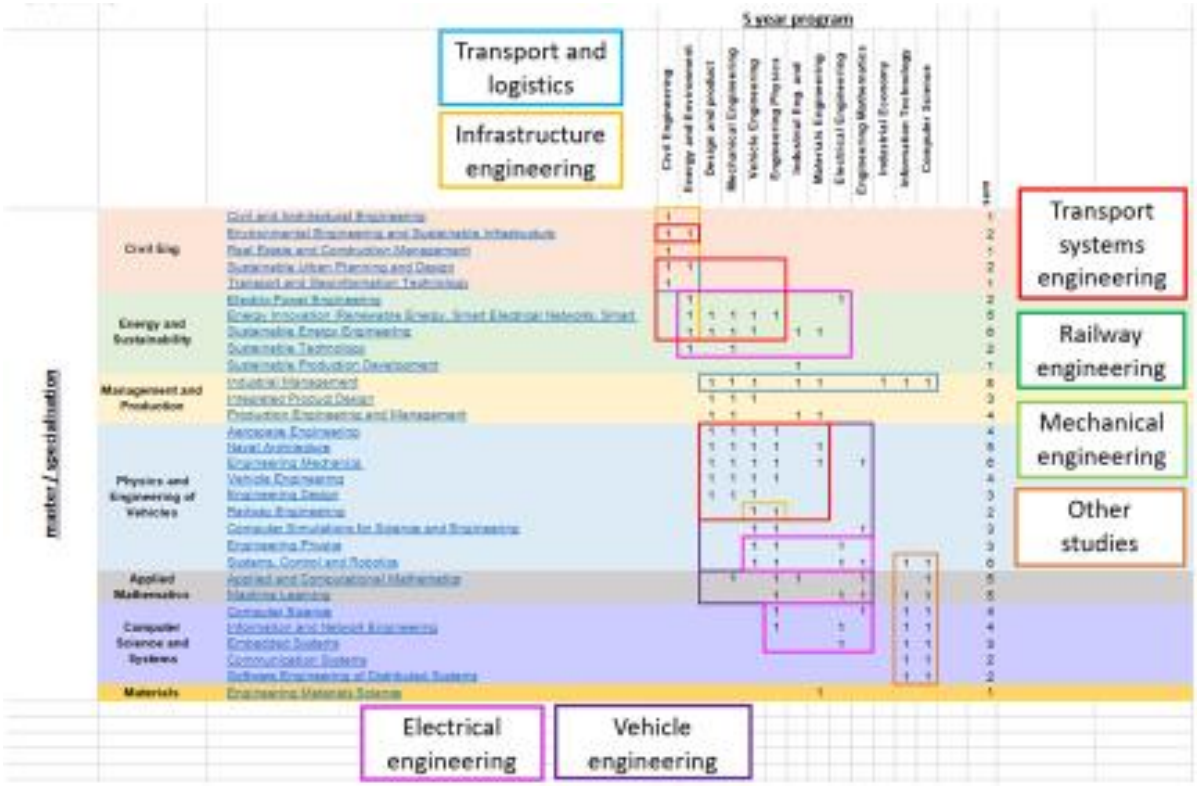

Figure 8: rail related study paths matrix at KTH Stockholm

The schemes produced in this section are a synthetic representation of the various study paths at the different partner universities combined with the RCM. The scheme allows a visualization of the connections between levels of study and the resulting cells.

In general, a Bachelor's course is a preparation either for a Master's or as direct access to the industry. If the students decided to pursue a Master, this allows them either to continue their studies with post-Master courses and PhDs respectively or to enter the industry right after. PhDs have different requirements in different countries and normally they do not require engineering related Master's degrees. Differently, in Germany and Sweden there are specific requirements for starting a PhD directly related to the area of study, e.g. admission to a PhD in engineering is only possible with an engineering degree. An example of study paths integrated with career maps for Sapienza University of Rome is in Figure 9.

The matrixes and schemas revealed 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 re-orientate during the studies makes it impossible to draw a complete picture of all the available study paths. Nevertheless, it is always possible, when starting in one of the generic fields outlined in the overview picture, to continue studying in this field up to the highest level (PhD).

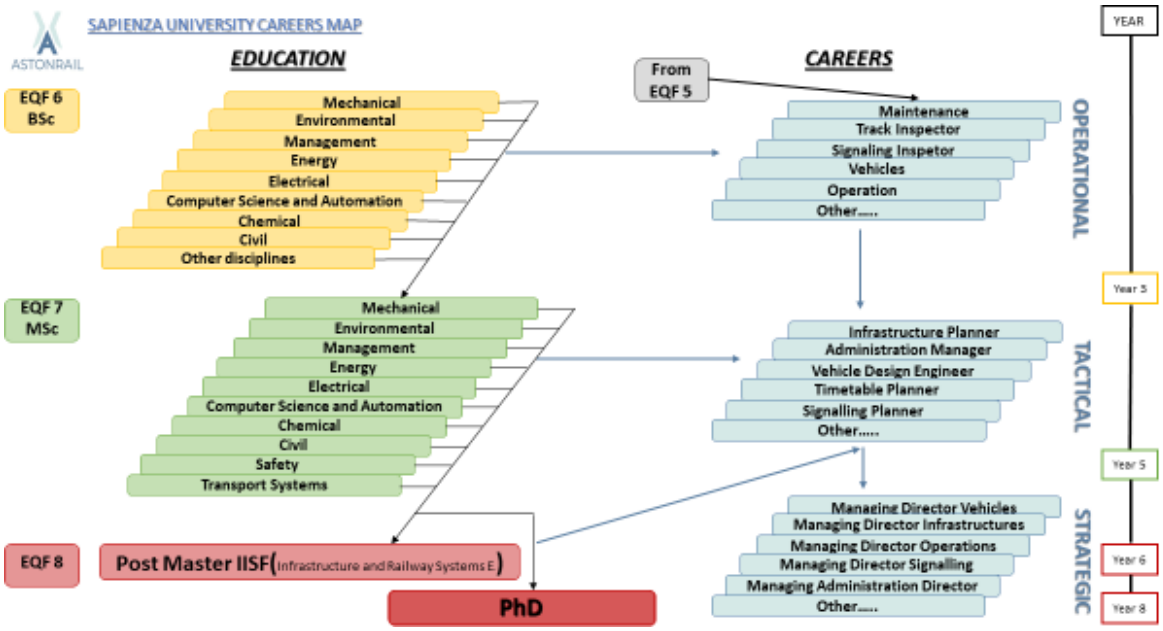

Figure 9: rail related education paths and career maps at Sapienza University of Rome

A study path is significant according to 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 Bachelor's level. The easiness to enter a certain Master program with a different Bachelor's degree is a *permeability* attribute.

In a 0-3 scale, the *permeability* of the various master programs are:

0) Master program(s) not available;

1) Master program(s) only accessible with a bachelors form the same path;
2) Master program(s) accessible with bachelor degrees from certain other paths;
3) Master program(s) accessible with bachelor degrees from nearly all other paths.

By this scale, it was possible to draw a more complete picture of the actual availability of study paths at the investigated institutions (Figure 10). 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. They are transport and logistics, energy and environmental studies and transport systems engineering. The permeability of the remaining paths mostly depends on each institution: e.g., University of Zagreb paths are all highly permeable.

The railway overview picture and the present research remain important and useful as in many cases the missing fields listed above are necessary additions to more traditional studies: e.g., engineers and logisticians do not only fulfil the traditional requirements, but also acquire versatile complementary knowledge beyond them.

4. Innovative methods in rail higher education and Intensive Study Course

One of the goals of the ASTONRAIL project is to produce a portfolio of new teaching and learning methods, approaches, policies and practices for rail skills development. For a better quality of learning, it is necessary to adopt for rail degree programmes the appropriate teaching approach, according to the context and the missions, in which students take joy and pride in their skills and knowledge. The ambition is that at the end of the programme, the graduates could be able to embrace prospective carrier in the railway sector in any European country. The key is never to lose the focus on student interest, knowledge and satisfaction. By comparing learning methodologies, the studies focused on the role of the teacher in rail higher education, examined, defined and confirmed for different rail specific subjects, types of delivery and learning activities. New approaches to assess the quality of learning outcomes focused on when and where the teacher should be acting as *Director*, as *Leading Learner*, as *Nurturer* and as *Facilitator* [11]. Identified potential improvements were also in *Classroom Assessment Techniques*, course-related and teacher-related student feedback.

		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

Figure 10: study paths at various universities qualified by the permeability criterion

In order to test different approaches on different topics an Intensive Study Course (ISC) took place at the University of Zagreb, Croatia in May 2022. Lectures at ISC covered five significant pillars of railway systems:

1) Infrastructure: wheel-rail contact, Building Information Modelling (BIM), predictive maintenance and asset management;
2) Operation, management and economics: movement of trains in a network, European Rail Traffic Management System (ERTMS), economic appraisals of services and optimization of operation and timetables
3) Rolling stock: traditional architecture of rail vehicles, innovative interior designs and inter-operable rail freight wagons;
4) Safety and security: safety principles for managing trains traffic and measures for protecting the railway system from malicious acts;
5) Technology: innovative approaches implemented in the railway industry and emphasized sustainability, low energy consumption, environment and decarbonisation.

A dedicated survey addressing 25 participating undergraduate, Master and PhD students from 12 countries collected suggestions on how to identify and establish the right balance between:

- Information acquisition and knowledge construction;
- Teacher-centered and student-centered learning;
- Lectures in classrooms and practices in laboratories;
- Exam-based assessment and work-based assessment;
- Student mobility and distance learning.

The survey included the feedback from the ISC, which included lectures, theoretical explanations for student, testing ideas with students actively involved, reflections and questions & answers sessions.

Within the closed-ended questions, the students evaluated the topics covered, the activities within the ISC, and general questions related to the impact of the ISC on them.

Figure 11 shows the evaluation results of topics on a scale from 1 (worst) to 5 (best). Interestingly, all topics got a minimum score of 4.14, which is proof of the quality of the ISC and all the activities that preceded the mentioned activity. Students rated the topic of technology the best (4.66) and operation, management, and economics (4.14) the lowest.

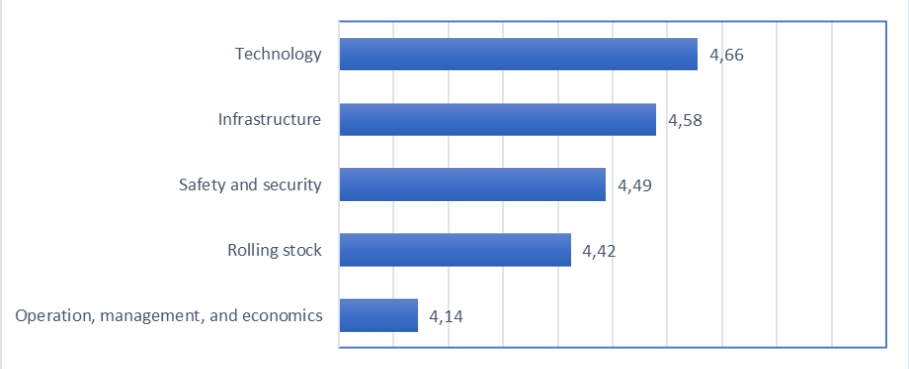

Figure 11: topics evaluation results (scale 1-5)

Evaluation of activities at ISC was also about the influence of ISC on improvements in communication, language, understanding of other cultures and support received from supervisors. Figure 12 shows the activity evaluation results. Students are most satisfied with the support received from supervisors (4.61) and least pleased with the improvement of English language skills (4.28).

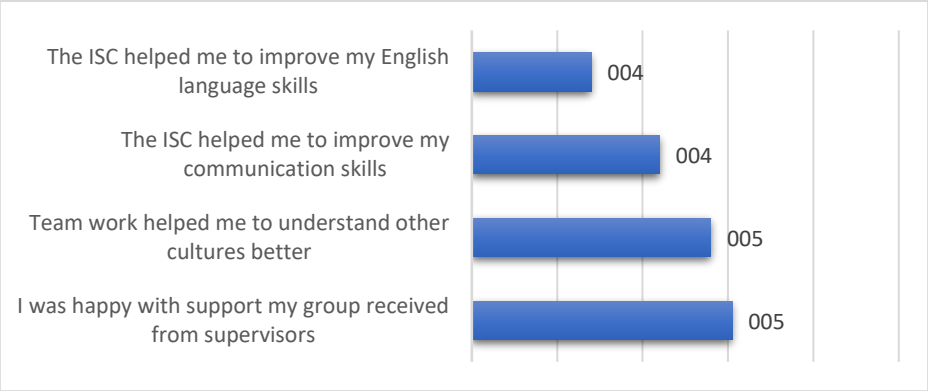

Figure 12: activity evaluation results (scale 1-5)

The results from other yes-no questions (figure 13) showed that the students rated 100% that they would recommend ASTONRAIL ISC to colleagues from their home university. Interestingly, they ranked 77.78% that one should not strive for a more significant number of classic theoretical lectures but should strive for more discussions (72.22%) and technical visits (94.44%).

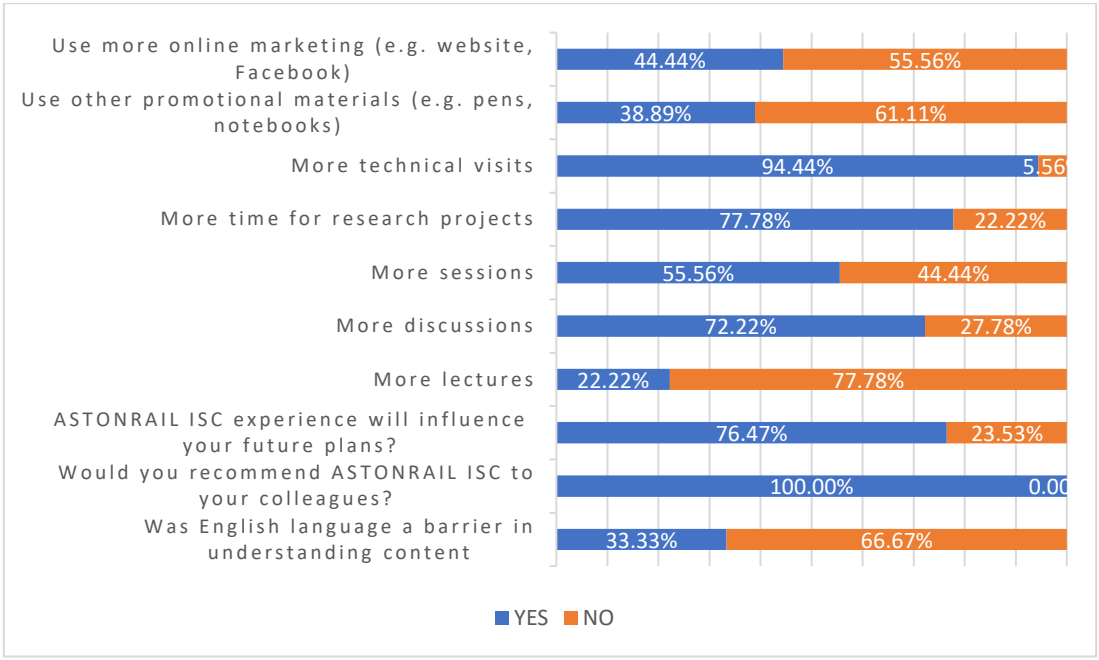

Figure 13: Yes-No Questions results

After the closed-ended questions, the students answered open-ended questions, about:

- Which part they enjoyed best and why;
- At which extent the English language was a barrier to understanding the content of the lectures;
- What they would recommend about the ISC to colleagues from their home university;
- Overall, what was good about the ISC;
- Overall, what was bad about the ISC;
- At which extent the ISC experience will influence their future career plans.

In response to the above questions, they concluded that they enjoyed the most because of discussions between students and teachers, practical teamwork, group work, discussion, sharing knowledge and proposing innovative ideas. In most cases, the English language was not a barrier to understanding the

content of the lectures. In contrast, others stated it was barrier because they are not using English language on daily basis and because of specific terms used at ISC. All students recommend ASTONRAIL ISC because of the great and exciting experience, new knowledge, meeting new people and a lot of practical and group works. Overall, many things were considered positive at ASTONRAIL ISC, such as the opportunity for discussing and developing conclusions by working in groups, lots of practical teamwork, great speakers with provoking discussions, multicultural backgrounds, improving English skills and well-educated professors and students. Overall, a few negative things emerged, such as long sessions with a lack of breaks during lectures and sometime too heavy lectures. Concerning the possibility that ASTONRAIL ISC experience will influence their future career plans, students highlighted that they got ideas for future innovations, which will help them choose their professional path, they improved their knowledge and language skills and appreciated the great networking.

5. Conclusions and next developments

Important results in the first part of ASTONRAIL project were in particular the structured acquisition of rail-specific education information becoming accessible for analysis and search of actions dedicated to fill some of these emerging gaps between higher education and rail employers' needs.

The developed database is ready for feeding a website so that prospective students could use it as a guidance to choose their course of study. The current dataset research amply supported the widespread impression of railways. Furthermore, the analysis of rail industry expectations and requirements for skills development highlighted that the rail transportation market is currently changing in many aspects, including strategic, technical, operational, digital, telematics and informatics. Mapping out the rail higher education provision against industry expectation is the basis for the identification of gaps and mismatches. Some of these gaps emerged from survey on employers, analysis of connections between educational paths and career, as well as from the feedback of the Intensive Study Course. In parallel, identification and tests of new teaching and learning methods with potential to improve the current rail higher education provision took place. The next steps will be the assessment of the attractiveness of the rail education and careers by the students, which will be under evaluation by means of focus groups and meetings among students and professionals in the rail sector. Moreover, the project will produce a handbook and technical specification profiles for the building of a skilled workforce through next generation methods, policies and practices of effective rail higher education techniques and mechanisms.

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