Employment and skills in the rail sector:

Impact analysis of Shift2Rail's innovation programmes

Human Capital Report Series

TNO innovation for life

Shift2Rail Moving European Railway Forward

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Summary

Goal, methodology and assumptions

S2R is an innovation initiative of the European Union and the railway sector for new technologies into the railway sector. The results of this S2R-innovation initiative need to be implemented into the sector over time. The S2R-initiative consist of five major Innovation Programmes (IPs) that themselves consists of a set of demonstrations of technical achievements: Technology Demonstrators (TDs), Integrated Technology Demonstrators (ITDs) and System Platform Demonstrators (SPDs. It is clear that the results of the innovation programmes will have an impact on the skill requirements of many occupations in the rail value chain. The aim of this report (D2) is to identify skill gaps in the railway sector connected to these IPs and TDs. To identify skill gaps, an analysis of the skill requirements is made for each of the IPs. This analysis consists of a best-estimation of the impacts of S2R IPs on the required skills within the sector. An assessment will also be given on the whole rail value chain.
Skill gaps are recognized as those changes in required skills that will not be solved if no change in current (company) policies follows. Changing levels of new skills demands will require interventions at the company level (and possibly sector level) to deal with the changes. These interventions are described in following reports D3a and D3b.

Overview of possible impact on required skills

To assess skill changes, the focus has been of recognisable occupations from the rail system. This report shows the results of the analysis of the impact in eight occupational categories. The occupations have been selected to represent a spread of occupations over the International Standard Classification of Occupations (ISCO) levels. This ISCO-system is a classification of occupational groups managed by the International Labour Organisation (ILO). Its structure follows a grouping by education level: ISCO-1 is academic jobs – ISCO-9 is occupations with no education required.

To understand changes in required skills in these occupations, the following separate analyses have been made:

- Changing conditions in the railway sector related to skills,
- Changes in task environment,
- Changes in separate skills (STEM, organisational, communication and social skills).

Skill changes need to fit the changing conditions and task environment. The distinction between STEM (science, technical, engineering, mathematics), organisational, communication and social skills is now the accepted approach used by international agencies such as the OECD (PIAAC), Cedefop and Eurostat. For sectors, mapping these changes allows to formulate new requirements to companies and educational actors.

Most changes in job demands appear to take place in 2024. The employment impacts are moderate until 2021 and then increase steadily in the following years. The main reason for this is that in the calculations, we accounted with the technology readiness level (TRL) of the different projects in the S2R-research programme: most of the projects expect to show their main results at the end of a period of four years. In this report, we underpin our expectation that this implementation will be the earliest impact date. In practice, most impacts will probably be later in time because of required changes in legislation, education and other institutional requirements. These institutions change slower than technology.
Four directions in (conflicting) job demands are visible in the future: more standardization of work, less standardization of work/more demands, less psycho-social risks and more

(Information and Communication Technology (ICT)) support. The following graph shows the conflicting trends (Figure i).

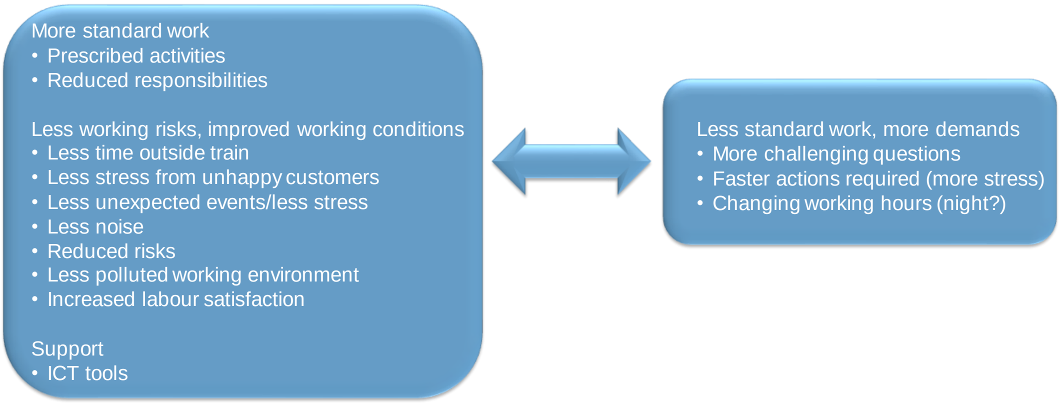

Figure i Conflicting demands as result of the IPs

The conflicting demands in the new working environment result in different skill impacts:

› At the level of task environment, there is a shift towards more use of ICT, systems, materials and production processes (ICT, ICT tool usage, system specifics, materials use, production process), but also tendencies to simplification of tasks and even redundancy of jobs;
› At the level of Science, Technology, Engineering and Mathematics (STEM), social, communicative and organisational skills, most of the changes are related to STEM-skills needed in the future. The different IP-programmes demand different technical knowledge to be developed. Next to STEM, there are rising social demands, communicative demands and demands on organisational capabilities. All demands are rising in all jobs, except for train drivers. For each of the job categories, the required competencies (or abilities) needed in the future to deal with these technologies have been judged separately. ‘Common sense logic’ dictates that operations and management have limited ICT-knowledge, but a lot of (traditional) operational knowledge. Engineers should be up-to-date, whatever the technology.

In general, the employment levels in the railway sector will change as a result of continuous innovation and re-engineering of processes. The IPs will help the sector to become more efficient. The precise impact on employment levels needs to be studied in the future. The skill changes have different outcomes depending on the type of job. The changes will also be different for the separate parts in the rail value system. From the current analysis, it is clear that manufacturers (components and trains) and system integrators will need to have all of their parts (development, manufacturing) move up the skill chain to the academic (engineering) level: all STEM-domains will need to be top-level to develop and manufacture these future elements and systems, but also to be able to understand the requirements from operators and infrastructure managers. Operators and infrastructure managers will need to step-up their ability to work with the other actors in the rail value chain, certainly in a rail market in which these actors are not integrated into their operations.

Conclusions and questions for future research

The following conclusions can be deduced from the analysis in this report:

- The IPs show impacts over time on employment levels. These levels are not studied in this report. Future research will need to look at this topic;
- In terms of skill changes, all job categories show a shift in the need for more ICT and (broad) technical skills. All job categories except train drivers show a shift in all types of skills to higher levels (academic engineering levels). In this sense, all occupations, except train drivers, show skill gaps that will need to be addressed by the rail organisations in the future years;
- The impacts have been calculated over a period of 2 to 6 years. The development seems to start with strong impacts at the beginning of this period and at the end of the period under observation.

Other questions for future research relate to:

- Following-up in time the predictions made;
- Broadening the selection of occupations for analysis;
- Including the technical experts developing the S2R-technologies in future estimations;
- Considering differences between countries;
- Understanding the impact of the IPs on the combination of existing and new technologies;
- Understanding how new technologies induce new services in the railway sector (with implications for jobs);
- What is the impact of different organisational models (for example: more centralised or more decentralised organisational models) used by companies on innovation impact?

The current report has been discussed with stakeholders in the railway sector and the conclusions of these discussions are integrated in report D3b.

Abbreviations

- ATO = automatic train operation
- COMM = communication competences
- IPs = Innovation Programmes
- ICT = competences and knowledge to use and develop information and communication technologies
- ISCO = International Standard Classification of Occupations
- ISCED = International Standard Classification of Education
- ORG = organisational competences
- S2R = Shift2Rail
- SOC = social competences
- STEM = science technology engineering and mathematical competences
- T = technical skills (see report for list)
- VET = vocational education and training

Contents

1 Introduction

1.1 Aim of the report

S2R is an investment initiative of the European Union and the railway sector for new technologies into the railway sector. The results of this S2R-innovation initiative need to be implemented into the sector over time. The S2R-initiative consist of five major Innovation Programmes (IPs) that themselves consists of a set of demonstrations of technical achievements: Technology Demonstrators (TDs), Integrated Technology Demonstrators (ITDs) and System Platform Demonstrators (SPDs. It is clear that these programmes will have an impact on skill requirements. In the previous report for this Human Capital-project (D1a) leading to this study, the general development in employment and skill changes over the past decade have been investigated. That report identified the current level of employment and current skill use. It also identified the predictions made about employment and skill changes in the future. This information forms the context for this new analysis. We will refer here to these results of D1a.

The aim of this report (D2) is to identify skill gaps in the railway sector connected to the investment in innovation projects (IPs) by S2R. To deal with these skill gaps, six measures will be explored in connection to this report in the next report D3. To identify skill gaps, an analysis of the skill requirements is made for the IPs. This analysis will consist of a best-estimation of the impacts of S2R IPs on the required skills within the sector. The analysis is made for the whole value chain of rail, starting from some indicative jobs at the level of a distribution of International Standard Classification of Occupations (ISCO) levels. The work needed for these evaluations is considerable and therefore a complete overview of all railway sector jobs is not possible within the timing of this project. The scope has been limited to a selection of jobs, recognizable for the sector and which provide a first indication of what is to come. The results show main impacts for train operators (passenger, freight) and infrastructure managers. However, there will be a separate analysis for manufacturers and system integrators.

The objective of the methodology is to achieve the following:

Determine the impact of the S2R work programme on the level of required skill levels.

1.2 Definitions

This report will focus on skills. The following definitions are important:

- Skills:
  - Task environment: task environment is seen as those elements that could influence the execution of tasks such as use of ICT, systems, materials and production technologies. Work can become more complex or simpler. The general change will be described.
  - Skills: in most discussion about skills, authors focus on the knowledge, competences and attitudes required to perform an occupation. In this report, skills are limited to knowledge and competences. Knowledge is seen as the required knowledge areas (Science, Technology, Engineering and Mathematics areas) and competences are the ability to deal with colleagues, customers and managers (social competency); the ability to read and write (communicative competency); and the ability to plan and prepare work (organisational competency).

- Skill gaps are recognized as those changes in required skills or employment that will not be solved if no change in current (company) policies follows. Changing levels of employment and new skills demands will require interventions at the company level (and possibly sector level) to deal with the changes. Such interventions will be needed, even if general employment levels may seem to be declining.

1.3 The targeted technological change of S2R

The starting point for the analysis in this report is the targeted technological change by the S2R-initiative. It is appropriate to provide a short overview of the objectives of these programmes.

The work conducted within the Shift2Rail framework is structured around five asset-specific Innovation Programmes (IPs), covering all the different structural (technical) and functional (process) subsystems of the rail system.
The European Commission is working towards the creation of a Single European Railway Area (SERA), and promotes a modal shift from road to rail in order to achieve a more competitive and resource-efficient European transport system. Rail transport should be a more competitive and resource-efficient part of the European transport system. The ultimate goal of the programme is a railway system of the future, built by European companies and helping the European passengers and companies. The separate objectives of the programmes are: the introduction of better trains to the market (quieter, more comfortable, more dependable, etc.), which operate on an innovative rail network infrastructure reliably from the first day of service introduction, at a lower life-cycle cost, with more capacity to cope with growing passenger and freight mobility demand (*website S2R*). The programme consists of a set of demonstrations of technical achievements: Technology Demonstrators (TDs), Integrated Technology Demonstrators (ITDs) and System Platform Demonstrators (SPDs).
The five programmes need further clarification and it is opportune to indicate some first impacts of the programmes on different occupational groups in the railway sector:

- **IP1 - Cost-efficient and reliable trains, including high-capacity trains and high-speed trains**
  This programme focuses on two main topics:
  - Lighter, more flexible and more resilient components with less environmental and systems impact: traction systems, car body shells, running gear, new braking systems, innovative doors, new designs and architectures of train interiors;
  - Information systems support train control and monitoring systems (TCMS), but also to support information to all stakeholders on the train.

  These projects mainly impact the jobs connected to building the trains and the software systems. In the train operation itself, main impacts will be on management, engineering and maintenance workers;
- **IP2 - Advanced Traffic Management and Control Systems**
  The objectives are the development of a new reliable Communication System, the expansion of the ideas on Automatic Train Operation (ATO) to other parts of the rail transport system and to virtually connect trains, and integrating control systems in the train so constraints of the external physical infrastructure and internal integrity are overcome. Trains should also become sources of information using sensing technologies to support better safety and operation. Better pre-testing of components should help achieve better lifetime performance of components. Improved interoperability of systems and rules and overall interconnectivity should be achieved via smart equipment, connected to the new infor-

mation supply. All information flows should be integrated into an optimised Traffic Management System. The observation is made that current systems do not sufficiently take advantage of existing 'new' technologies and practices. Possibilities for enhanced traffic management (including predictive and adaptive operational control of train movements) and better customer information are missed. The capabilities of these systems can be expanded. In this sense, most of these systems are already partially in place, but need to be updated, integrated and upscaled. All operational jobs will be affected by the changes: management, engineering, maintenance staff and operational jobs;

- **IP3 - Cost-Efficient and Reliable High-Capacity Infrastructure**
  This programme is mirroring the second programme. Now the infrastructure is the main carrier for innovations. The improvements are sought in *Enhanced Switch & Crossing Systems, a Next Generation Switch & Crossing System*, an optimized and next-generation track system. Data integration, connectivity and control systems are core components of this technological change. All of this leads to more 'pro-active' components in the systems, delivering masses of data that need to be channelled through *Dynamic Railway Information Management System* (DRIMS) and the *Railway Integrated Measuring and Monitoring System*, leading to high-quality input to the Intelligent Asset Management Strategies. With such integrated systems, smart power supply, smart metering and future stations become a reality. Infrastructure accounts for approximately one-third of the railway's operating costs. A significant part of these costs is related to labour-intensive maintenance, most of which is preventive, although ad hoc interventions are also needed when faults occur - and these can be particularly costly and disruptive. The new technologies will mainly impact management and maintenance staff;
- **IP4 - IT Solutions for Attractive Railway Services**
  The basis of the innovations in this programme is the *'Interoperability Framework'* to facilitate multimodal travel in a highly diverse environment and with many transport modes. With this basis, data can come available and get connected to deliver new tools such as the *Travel Shopping* application, the *Booking & Ticketing* engines giving the traveller easy access to his/her journey simplifying the traveller's life; the *Trip-tracker* updating all elements and rights to travel; a personal and secured *Travel Companion*. The integration also requires new *Business Analytics* to manage those data. Eventually, rail must respond to customer needs to support anytime, anywhere, door-to-door, intermodal journeys encompassing distinct modes of transportation. The innovations will impact management, coordinators, and operation in the stations and on the trains;
- **IP5 - Technologies for Sustainable & Attractive European Rail Freight**
  This programme in fact focuses on all the elements in the previous four programmes, but now specifically for freight transport. The idea is to generate more data on freight operations and trains systems and integrate these into better information systems. Operational performance of freight systems should improve with *Freight Electrification, Brake and Telematics*, better *Wagon Design* and *New Freight Propulsion Concepts*. Connecting these things should also allow *Autonomous train operation* in the freight domain. Not only the train systems need renewal, the context should change: *Novel Terminal, Hubs, Marshalling yards, Sidings, Access & Operations* aim to improve service planning and operation, and there should also be better *Implementation Strategies and Business Analytics* to provide guidance on implementing new technology solutions on a large scale. Although rail freight markets within the EU have been open for a number of years, the modal share of intra-EU rail freight transport has slightly declined in the past decade. The industry's stagnation can be explained partly by the existence of legal barriers restricting competition (including the track access regime, taxation, etc.), but also by problems of an operational and technical nature, which impact the overall capacity and performance of the sector. With the changes, all occupational groups in the freight will be affected.

The programme overviews also contain insights into possible new market demands and improved growth of passenger numbers and freight tonnage. These improvements are important, but for this study, the assumption is that future market demand is difficult to estimate. Market demands is therefore considered to remain stable at the current levels. At this moment, the sector is still experiencing market decline in a number of areas.

1.4 Framing estimations of future skill development

This report tries to make estimations for changes in skill demands. The driver for change is technology. We must however understand that the introduction of any new technology needs an adoption process in which not only technologists and investors play a role. Other factors also influence the process:

- the current state of technology ('vintage' of technology),
- the resistance and cooperation of stakeholders in the field,
- the competing forces of non-rail technologies,
- the interconnection of old and new technologies.

These factors all play a role in (mainly) slowing down the adoption rate of new technologies. The following example shows how the introduction of ERTMS probably will affect future personnel and skill development. For the Dutch situation, for example, some 70% of the Dutch rail control/protection system in the rail system are based on relay technology that dates back to the beginning of the 1950s (reconstructed with help from the Marshall Plan)[1]. This infrastructure is therefore very outdated and must be replaced in the future. Figure 1.1 shows what will happen, according to our discussions with experts in the field. Developments have been exaggerated for sake of the argument.

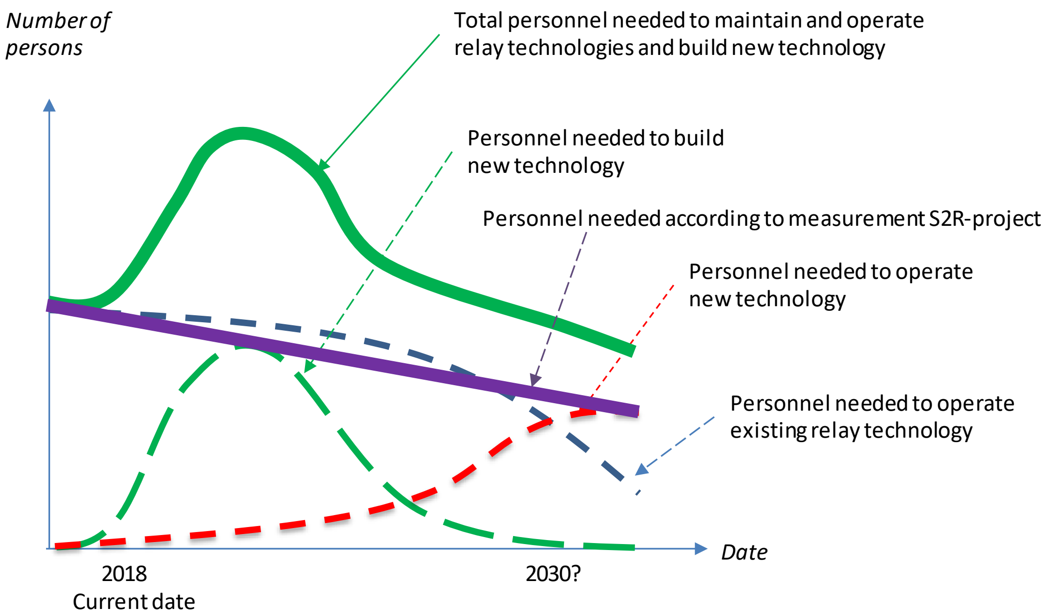

Figure 1.1 Estimation of development of personnel in Dutch rail system working with old and new relay technology

[1] Ammelrooy, P. van (2019). Antieke bewakers langs de spoorbaan. *De Volkskrant*, March 27th, 24-25.

Clarification of the figure:

- The blue dotted line is the total number of personnel required to maintain and operate the current rail control/protection system (largely based on relay technology from the 1950s). Learning effects and growing experience help to reduce costs over time and lead to lower head counts. That number of personnel will not go down to zero because in the Netherlands not all rail lines will be converted to ERTMS;
- The red dotted line is the total of personnel to maintain and operate the new rail control/protection system. The size of this group will be smaller than that of the old rail control/protection system (new systems are more robust, etc.). The numbers of persons connected to this technology will rise, along the investment in this technology. Over time however, this rise will slow down and at a certain moment, growing experience will tend to reduce costs and ‘head count’;
- The green dotted line is the total of personnel needed for the building of the new technology.

The conversion will take many years. So, the total number of staff (green full line) you need is the sum of staff that continues to maintain the old rail control/protection system, the maintenance of the new rail control/protection system and the personnel needed for the conversion. In our view, you get a peak demand in personnel and this question will not only take place in the Netherlands. On a European scale and even a world scale, there are many ambitions at the same time.
The leap to new technology will not be a full changeover to this technology. The figure shows how the staff shift is currently moving to new relay systems. In practice, the need for staff who can work with the old technology diminishes only at a slow pace. New staff is needed for the new technology, in addition to the current staff. This means that network operators will require both type of skills at the same time. 'Old staff' can move on to the new technology, depending on retraining. The total number of staff therefore continues to rise, despite the renewal of the technology. In addition, for the replacement of the technology there will be a peak in special staff (mainly hired contractors (installation) to replace everything). This need is made visible with the green dotted line in the figure, which peaks in a couple of years. The proportions may not be right, but the picture is what occurs. The lesson is that the new technology developed by S2R will on the short term only lead to a sharp increase in staff and new required skills, and that the savings of the investments in terms of lower personnel needs will only be visible in the long term. The new technology is always better than the past technology: more efficient, more robust, more redundant (in components) and easier to use and maintain. These technologies are however more complex than the older technologies. A risk is that the technology could be so complex that if it really breaks down there is insufficient knowledge to recover quickly. Recent examples from neighbouring areas are the computer problems at Schiphol's traffic control, which meant that many flights had to be cancelled. The economic consequences of such breakdowns can be important. For rail operators, the skills issue is equally complex: which knowledge to maintain, but also when to have the new knowledge ready and operational?

In our analyses, we do not have sufficient information on the available technology, nor on the costs needed to integrate the old technologies with new technologies. The main assumption in this report is that the new technologies are implemented the day they are developed. Our estimations are therefore the earliest possible indication for changes in personnel demand. In the figure above, the purple full line is what we are able to estimate. The figure shows what has not been taken into account.

1.5 Structure of the report

The rest of the report is structured as follows. The methodology for the report is clarified in Chapter 2. The general results are broken down at the level of eight specific railway occupations in Chapter 3. The spread in jobs shows possible changes between jobs in the railway sector. A separate section is on the skill demands for the different parts of the rail value chain. The impacts on skill gaps are discussed in Chapter 4. The main conclusions and remaining discussion points are presented in Chapter 5. The report contains one annex. For any interested party, an excel files contains the detailed material for the report.

2 Methodology: Measurement of impact on skills

The general approach for the analysis of skill changes in the rail sector is explained in this chapter.

2.1 Expert judgement

S2R JU asked TNO/NewRail to use an (own) expert assessment to come up with evaluation of the possible impacts of the projects. The following experts have been engaged in the evaluation:

- Dr. Ming Chen (TNO): rail expert;
- Prof. Dr. Steven Dhondt (TNO; KUL): employment and skills expert;
- Dr. Frans van der Zee (TNO): employment and skills expert; economics;
- Dr. Dewan Islam (NewRail): rail expert;
- Prof. Dr Mark Robinson (NewRail): rail expert.

With these experts, we cover expertise from the railway sector, but also expertise from other sectors. For the evaluations, use has been made of S2R information (including the S2R work programme).
This report contains these evaluations.

2.2 Assumptions used in making the evaluations

In preparing the evaluations, several assumptions have been used (see also Section 1.4). Each of these assumptions can be changed and the impacts can be further investigated:

- For the estimation of overall impacts at the level of a separate innovation programme, we assume that we can aggregate the information for sub-levels of the programme;
- Estimation of possible impact of a project in time. All the projects have a different time-to-market. The only information available to the research team was information about the Technological Readiness Level (TRL) of each of the sub-level projects. TRLs are used in IPs to understand how market-ready the innovations will be. These TRL-levels are translated into timing of implementation (number of years), using the following rules:
    - TRL-7: 2019 + 2 years,
    - TRL-6: 2019 + 3 years,
    - TRL-5/-4: 2019 + 4 years,
    - TRL-3/2/1: 2019 + 5 years.

  An assumption connected to this assumption is that on this date, the projects will have a direct and immediate impact on jobs and skills. In practice, we may assume that adoption will never be immediate (see also Section 1.4) and that there will be considerable differences between countries and companies. The expectation is that this report will show the fastest possible impact. In practice, employment and skills impacts will be spread out over more years. We will show in Chapters 3 and 4 when these impacts will be expected at the earliest;
- Impacts have been calculated at the level of separate jobs (see Chapter 4). The overall impact in the railway sector is seen as the aggregation of the separate calculations. The jobs have been selected to represent the distribution of jobs.

2.3 Method for evaluating skills impact

The starting point for the analysis is the overview of the S2R-IPs. These projects have been broken down into separate parts. Each of these separate parts have been analysed for the following elements:

› Content: what is the innovation about? There are five major IPs consisting of a total of 42 separate TDs focusing on specific measures for improvement (see Annex 1 for full overviews of projects). For each TD, we investigated which six sectors (rolling stock, operation of the rail system, on-board train operation, infrastructure, freight operation, ticketing) and sub-sectors (control, maintenance, manufacturing and installation, planning, operation, service, driver, manufacturing, marshalling yards, terminals) were impacted by these TD measures;
› What is the TRL-level and therefore the possible impact in time (market introduction date)?
› Which jobs are impacted by the innovation project? The project is aimed at a selection of jobs that represent major activities in the railway sector. The jobs have also been selected to show a distribution to most of the ISCO-levels. The following list does not cover ISCO-level 8:
  - Rail operations manager (ISCO-1): including managers working on the control centres or signalling (German: Fahrdienstleiter); railway station manager; logistics and distribution manager;
  - Engineer (mechanical, electrical, ICT) (ISCO-2): including electrical engineers, ICT-engineers, mechanical engineers (for maintenance or rolling stock/trains) (German: Farhzeug-Instandhaltung);
  - Logistics engineer (ISCO-2);
  - Dispatch worker (ISCO-3): for organisation and planning of rolling stock and shunting operations (German: Disponent);
  - Rail maintenance technician; Train maintenance technician (ISCO-3): including rolling stock engine tester, rolling stock engineering technician;
  - Rail logistics coordinator (ISCO-4): for both assets and for cargo (German: Ressourcenplaner in der Logistik für Assets/Züge und für Güter);
  - Train attendant (ISCO-5): (German: Zugbegleiter/-chef);
  - Train driver (ISCO-7): including shunting, rail switch person.

For the skills impacts, the following assessments have been made:

› What conditions for conducting the tasks are changing? This is a qualitative assessment of changing working conditions connected to each of the tasks;
› What task environment will be changing connected to each of the tasks? This is also a qualitative assessment, stressing the most likely impacts on tasks;
› What skills will change: we use the distinction made in the first report (D1a), following the distinctions in skills used by the OECD, Cedefop and Eurostat:
  - STEM Skills: these skills are connected to the required knowledge to perform a task;
  - Communication Skills: reading, listening, writing and presentation skills;
  - Social Skills: capability to build relationships with colleagues, management and clients (etc.);
  - Organisational Skills: planning, preparation, analysing of work.

3 Results 1: Overall view of skill impacts

This section presents the overall view of changes in skill levels for the railway sector. In the following sections, more details are provided. This section gives a general impression of the outcomes of the analyses.

3.1 Timing of changing job demands

In Tables 3.1a and 3.1b, a summary is made of the changing conditions and the possible skills impacts of the S2R-projects. The following separate analyses have been made:
- Changing conditions in the railway sector related to skills (table 3.1a);
- Changes in task environment (table 3.1b);
- Changes in separate skills (STEM, organisational, contact and social skills) (table 3.1b).

Table 3.1a Overview of changes in conditions in the railway sector

2021	2022	2023	2024
• Prescribed activities • Less unexpected events/less stress • Increased labour satisfaction • Less polluted working environment • Reduced responsibilities	• Prescribed activities • Less stress from unhappy customers • More challenging questions • Supported by ICT tools • Increased labour	• Prescribed activities • Less unexpected events/less stress • Less noise • Reduced responsibilities	• Prescribed activities • Less unexpected events/less stress • Increased labour satisfaction • Less polluted working environment • Reduced responsibilities • Changing working hours (night?) • Less noise • Faster actions required (more stress) • Less time outside train • Reduced risks • More challenging questions • Supported by ICT tools

Table 3.1b Overview of changes in tasks and required skills in the railway sector (=: no change)

Development	2021	2022	2023	2024
Task environment	Simplification ICT System specifics	ICT-Tool usage	Simplification ICT System specifics	Simplification ICT System specifics Material use Production process Redundancy ICT-tool usage
STEM Knowledge Areas	=	Materials ICT	ICT-levels TCMS Specific	Materials Manufacturing Operational knowledge Communication technology Technical system Traffic management ICT (cyber) ICT

Development	2021	2022	2023	2024
				ICT Control systems
Communication Skills	=	=	=	Rise
Social Skills	=	Rise	=	Rise
Organisational Skills	=	Rise	=	Rise

3.2 Changing job demands

Most changes in job demands appear to take place in 2024. The impacts are moderate until 2021 and then increase steadily in the following years. The main reason for this is that in the calculations, we accounted with the technology readiness level (TRL) of the different projects: most of the projects expect to show their main results at the end of a period of four years. Four directions in (conflicting) job demands are visible: more standardization of work, less standardization of work/more demands, less working risks and more (ICT) support:

- More standard work:
  - Prescribed activities;
  - Reduced responsibilities;
- Less standard work, more demands:
  - More challenging questions;
  - Faster actions required (more stress);
  - Changing working hours (night?);
- Less working risks, improved working conditions:
  - Less time outside train;
  - Less stress from unhappy customers;
  - Less unexpected events/less stress;
  - Less noise;
  - Reduced risks;
  - Less polluted working environment;
  - Increased labour;
  - Increased labour satisfaction;
- Support:
  - Supported by ICT tools.

3.3 Task environment

In terms of task environment, the impacts are in two different directions. Five impacts are on use of ICT, systems, materials and production processes (ICT, ICT tool usage, system specifics, materials use, production process) and two on reduction of possibilities (simplification, redundancy).

3.4 Skill components (general skills)

Most of the changes are related to the STEM-skills in the future. For the other three categories (communication, social, organisational), there seems to be a rise in requirements. For STEM-skills, in connection with the analysis of task environment, there will be a trend that becomes more obvious, that is insisting on more technology and supporting knowledge sources.

The following more technical areas related to knowledge are connected to the different IP-programmes and provide the main areas for further assessment.

Table 3.2 shows the overlap between the different IPs in required skills and competencies from job categories. To reduce this complexity, the overlap has been eliminated and the number of jobs has been limited to three categories:

1. Research by Stanford University (Bloom) and London School of Economics (Van Rheenen) uses a methodology to analyse impact of technology by classifying technology into impacts on work. They reduce the complexity of technologies into three types: information technology, communication technology, automation. Most technologies can be categorized under one of these 3 headings. Bloom et al. (2014) predict that information technology will enlarge work tasks, reduce management control from above. Communication technology does the reverse: leading to more specialized tasks, more control from higher management layers. Automation eliminates jobs. Using this insight, the major technologies used in the IPs can be classified into these three categories;
2. The eight jobs can be reduced into managerial jobs, engineering (development) jobs, and operational work (maintenance, driving, control). This certainly simplifies the analysis;
3. For each of the job categories, the required competencies (or abilities) needed in the future to deal with these technologies can be judged separately. This does not deliver information about a ‘skill gap’, mainly because the current competency levels are not precisely known. ‘Common sense logic’ dictates that operations and management have limited ICT-knowledge, but a lot of (traditional) operational knowledge. Engineers should be up-to-date, whatever the technology.

Table 3.2Required (new) knowledge areas for rail professionals

IP and knowledge area	Rail operations manager (ISCO-1)	Engineer (mechanical, electrical, ICT) (ISCO-2)	Logistics engineer (ISCO-2)	Dispatch worker (ISCO-3)	Rail maintenance technician; train maintenance technician (ISCO-3)	Rail logistics coordinator (ISCO-4)	Train attendant (ISCO-5)	Train driver (ISCO-7)
IP1. Cost-efficient and reliable trains, including high-capacity trains and high-speed trains								
Information technology • Control systems • Monitoring and data collection, analysis • Autonomous train operation	+	+	+	+	+	+	+	+
Mechanical and electrical engineering		+			+			
IP2. Advanced Traffic Management and Control Systems								
Communication technology • Adaptable communications • Smart radio technology Information technology • Virtualization of processes • Digitalisation • Sensing technologies • Cyber security	+	+	+	+	+	+	+	+

IP and knowledge area	Rail operations manager (ISCO-1)	Engineer (mechanical, electrical, ICT) (ISCO-2)	Logistics engineer (ISCO-2)	Dispatch worker (ISCO-3)	Rail maintenance technician; train maintenance technician (ISCO-3)	Rail logistics coordinator (ISCO-4)	Train attendant (ISCO-5)	Train driver (ISCO-7)
Management systems Operational management, in-depth rail knowledge Testing technologies Formal methods and standardisation Traffic management	+	+	+		+	+		
IP3. Cost-Efficient and Reliable High-Capacity Infrastructure								
Communication technology • Connectivity Information technology • Data integration • Control systems • Information Management System • Integrated Measuring and Monitoring System • Intelligent Asset Management Strategies Sensing technologies • Smart power supply • Smart metering	+	+	+	+	+	+		
Switch and crossing technologies Maintenance systems, preventive and curative approaches Station management	+	+	+	+	+	+		+
IP4. IT Solutions for Attractive Railway Services								
Communication technology • Interoperability Framework Information technology • Data collection technologies • Social media use, application use • Big data analysis	+	+	+	+	+	+	+	+
Business Analytics Modes of transportation integration Behavioural knowledge (shopping behaviour)	+	+	+			+	+	
IP5. Technologies for Sustainable & Attractive European Rail Freight								
Communication technology • Telematics • Terminal technologies Information technology • Data analysis and management • Information systems • Autonomous train operation	+	+	+	+	+	+		+

IP and knowledge area	Rail operations manager (ISCO-1)	Engineer (mechanical, electrical, ICT) (ISCO-2)	Logistics engineer (ISCO-2)	Dispatch worker (ISCO-3)	Rail maintenance technician; train maintenance technician (ISCO-3)	Rail logistics coordinator (ISCO-4)	Train attendant (ISCO-5)	Train driver (ISCO-7)
Electrification Systems integration Service planning and operation Implementation Strategies Business Analytics Wagon Design New Freight Propulsion Concepts	+	+	+	+		+		

This outcome of this analysis in Table 3.4 provides a first insight into future changes in STEM-knowledge areas.

Table 3.4Required (new) STEM-knowledge areas for rail professionals

	Major activity categories: required ability in knowledge areas		
	Management jobs	**Engineering and development jobs**	**Operational work (maintenance, driving, control)**
Information technology			
Digitalisation Virtualisation of processes Data collection, monitoring Data integration Data analysis, Big data analysis Social media use, application use	Ability to understand the data flow and its meaning Ability to define right analytical questions	Ability to develop data models for monitoring Ability to define right analyses	Ability to understand outcomes of data analysis Ability to use information in broader tasks
Cyber security	Understanding and defining security requirements	Understanding and defining security requirements, formulating containment actions	Following assignments not to reduce security
Control systems Information Management System Integrated Measuring and Monitoring System Intelligent Asset Management Strategies	Ability to use different information systems Ability to develop strategies on basis of systems information Ability to understand in-depth working of processes and workings of these systems	Ability to define appropriate and fail-safe systems Ability to understand connection between different information systems	Ability to work with automated information signals

	Major activity categories: required ability in knowledge areas		
	Management jobs	Engineering and development jobs	Operational work (maintenance, driving, control)
Communication technology			
Sensing technologies Smart metering Smart radio technology Connectivity Adaptable communications Interoperability Framework Terminal technologies	Understanding impact of communication technologies	Ability to use wide variety of communication technologies to improve data transfer Solving interoperability issues	Understanding that assignments may come from other management levels thru CT
Automation			
Autonomous train operation Switch and crossing technologies Telematics Electrification Smart power supply Systems integration Wagon Design New Freight Propulsion Concepts Mechanical and electrical engineering	Ability to manage strongly automated processes	Ability to understand possibilities and make right cost-benefit approaches	Preparedness to work with automated systems Ability to report about performance of systems
Management systems			
Operational management, in-depth rail knowledge Testing technologies Formal methods and standardisation Traffic management Maintenance systems, preventive and curative approaches Station management Business Analytics Modes of transportation integration Behavioural knowledge (shopping behaviour) Service planning and operation Implementation Strategies	Ability to manage on the basis of data Ability to understand business analytics results and make decisions Ability to implement changes into organisations	Ability to overlook capabilities of different methods and to integrate strengths of different methods	Ability to bring in own practices into new management concepts ('workplace innovation')

3.5 In summary

In general, the skill levels in the railway sector will be changing as a result of continuous innovation and re-engineering of processes. The skill changes have different outcomes depending on the type of job.

4 Results 2: Analysis of changes in major job categories

4.1 Introduction

In this chapter, the impacts for eight major job categories in the railway sector are discussed separately. Each section in this chapter discusses major possible skill changes for eight rail occupations. This chapter ends with an overview of the impact of the skill changes at the level of the rail value chain.

4.2 Rail operations manager (ISCO-1)

Table 4.1 shows the major TDs that lead to a change in skill level of managers and when the (first) impact of the projects are expected.

Table 4.1 Overview of S2R-TDs and possible first market uptake for managers

Code	S2R-TDs	Market uptake
TD1.1	Traction System	2024
TD1.2	TCMS	2023
TD1.6	Doors	2024
TD2.1	Adaptable communications for all railways	2024
TD2.2	Railway network capacity increase	2024
TD2.3	Moving Block	2024
TD2.4	Fail-Safe Train Positioning	2024
TD2.8	Virtual-Coupled Train Sets (VCTS)	2024
TD2.9	Traffic management evolution	2024
TD2.10	Smart radio-connected all-in-all	2024
TD2.11	Cyber Security	2024
TD3.1 & 3.2	Switches & Crossings	2024
TD3.3 & 3.4	Track	2021
TD3.5	Bridges & Tunnels	2023
TD3.6-TD 3.8	Intelligent Asset Management (IAM)	2023
TD3.9	Smart Power Supply	2024
TD3.10	Smart Metering Energy	2023
TD3.11	Future (small) stations	2023
TD5.1	Freight electrification & telematics	2021
TD5.2	Access & operation	2021
TD5.3	Wagon Design	2023
TD5.4	Novel Terminal	2024
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of rail operations managers are mainly influenced by the IPs IP1, 2, 3 and 5. The strongest impact is expected in IP2 and 5.

Table 4.2 gives an overview of the changes in skills requirements.

Table 4.2 Overview of skills impacts of S2R-IPs on managers: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, changing working hours (night?), less noise, faster actions required (more stress); less time outside train, reduced risks, reduced responsibilities	ICT; System specifics; simplification	Operational knowledge, ICT-levels, TCMS	=	Rise	=
IP2	Less unexpected events/less stress, reduced responsibilities	ICT, System specifics, simplification, redundancy,	Communication technology, Technical system, Traffic management, ICT (cyber)	Rise	Rise	Rise
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities	Simplification	ICT	=	=	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, reduced responsibilities, less noise	Simplification, ICT; System specifics	ICT Control systems	=	=	Rise

The general impact seems to be less predictable work, improved working conditions and more need for ICT-knowledge (information and communication technology), but also possible risks of redundancy. At the same time, we can see that responsibilities are reduced in all IPs and that simplification of tasks is probable. This helps explain the reduced need for such rail operations managers in general. The skills demand however will rise in all skill domains.

When will these changes occur at the earliest date? As explained in the methodology section, we can only rely on the TRL-levels of the TDs (these are indicated by the research team as the readiness for the market uptake) to estimate possible implementation date for the technologies and thus requirement to have the skills in place. We will only focus on the timing of the STEM-skills, assuming that the required communication, social and organisational skill will be required at the earliest date possible. The following table lists the estimated earliest date for the STEM-skills.

Table 4.3 Overview of timing of skills impacts of S2R-IPs on managers: new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Rail operations manager (ISCO-1)	ICT	IP5: Telematics		IP1: TCMS IP3: Intelligent Asset Management	
	Technical			IP3: Smart Metering	IP2 IP3: Power Supply

Rail occupation	New STEM-requirements	2021	2022	2023	2024
	Traffic	IP3: Track IP5: Access		IP3: Bridges, Stations IP5: Wagon design	IP1 IP3: Switches & Crossings IP5: ATO; Terminal; Propulsion

4.3 Engineer (mechanical, electrical, ICT) (ISCO-2)

Table 4.4 shows the major TDs that either require a change in skill.

Table 4.4Overview of S2R-TDs and possible market uptake for engineers and when the (first) impact of the projects are expected.

Code	S2R-TDs	Market uptake
TD1.1	Traction System	2024
TD1.2	TCMS	2023
TD1.3	Car Body	2024
TD1.4	Run Gear	2022
TD1.5	brake	2023
TD1.6	Doors	2024
TD1.7	Modularity	2023
TD2.1	Adaptable communications for all railways	2024
TD2.2	Railway network capacity increase	2024
TD2.3	Moving Block	2024
TD2.4	Fail-Safe Train Positioning	2024
TD2.6	Zero on-site testing	2024
TD2.7	Formal methods and standardisation	2024
TD2.8	Virtual-Coupled Train Sets (VCTS)	2024
TD2.9	Traffic management evolution	2024
TD2.10	Smart radio-connected all-in-all	2024
TD2.11	Cyber Security	2024
TD3.1 & 3.2	Switches & Crossings	2024
TD3.3 & 3.4	Track	2021
TD3.5	Bridges & Tunnels	2023
TD3.6-TD 3.8	Intelligent Asset Management (IAM)	2023
TD3.9	Smart Power Supply	2024
TD3.10	Smart Metering Energy	2023
TD3.11	Future (small) stations	2023
TD4.1	interoperability framework	2024
TD4.2	Travel Shopping	2022
TD4.3	booking & ticketing	2022
TD4.4	Trip Tracker	2022
TD4.5	Travel Companion	2022
TD4.6	Business Analytics Platform	2022
TD4.7	Overall IP4 Coordination and demonstration	2021
TD5.1	Freight electrification & telematics	2021
TD5.3	Wagon Design	2023
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of rail engineers are influenced by all IPs. The impacts are in all directions. The strongest skill impact is expected in IP1, 2 and 3. IP1 and 5 also show growing employment demands.

Table 4.5 gives an overview of the changes in skills requirements.

Table 4.5 Overview of skills impacts of S2R-IPs on engineers: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, changing working hours (night?), less noise, reduced risks, reduced responsibilities, prescribed activities, faster actions required (more stress); less time outside train	ICT; System specifics; simplification, material use, simplification, production process	ICT-levels, TCMS, Materials, Manufacturing, specific, Operational knowledge, ICT	=	Rise	=
IP2	Less unexpected events/less stress, reduced responsibilities, prescribed activities	ICT, System specifics, simplification, redundancy	Communication technology, Technical system, Traffic management, ICT (cyber)	Rise	Rise	Rise
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities	Simplification	ICT	=	=	=
IP4	More challenging questions, supported by ICT tools, less stress from unhappy customers, increased labour satisfaction	ICT tool usage	ICT	=	Rise	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, less noise, reduced responsibilities	Simplification, ICT; System specifics	ICT Control systems	=	=	Rise

The general impact seems to be less predictable work, improved working conditions and a greater need for all kinds of technical knowledge, but also possible risks of redundancy. Even though we can see that responsibilities of engineers are reduced in all IPs and that simplification of tasks is probable, this reduction is limited in comparison to managers. In the longer term, simplification and less responsibilities reduce reliance on such rail engineers. The skills profiles however will rise in all skill domains, but most of all in the STEM-related field.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the STEM-skills.

Table 4.6 Overview of timing of skills impacts of S2R-IPs on engineers (mechanical, electrical, ICT): new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Engineer (mechanical, electrical, ICT) (ISCO-2)	ICT	IP5: Telematics	IP2: ticketing; tracker; analytics	IP1: TCMS; Modularity IP3: IAM; Smart Metering	IP2: Communication; Smart radio; Cyber; VCTS IP3 : Smart Power IP4: interoperability IP5 : ATO
	Technical	IP4: coordination		IP5: Wagon design	IP2: Block; Positioning; Methods
	Traffic	IP3: Track	IP1: run gear IP2: shopping; companion	IP1: brake IP3: Bridges; Stations	IP1: Traction; Doors IP2: Network; Traffic mgt; Testing IP3: Switches & Crossings IP5: propulsion

4.4 Logistics engineer (ISCO-2)

Table 4.7 shows the major TDs that either require a change in skill.

Table 4.7 Overview of S2R-TDs and possible market uptake for logistic engineers and when the (first) impact of the projects are expected.

Code	S2R-TDs	Market uptake
TD1.2	TCMS	2023
TD2.2	Railway network capacity increase	2024
TD5.1	Freight electrification & telematics	2021
TD5.2	Access & operation	2021
TD5.3	Wagon Design	2023
TD5.4	Novel Terminal	2024
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of rail logistics engineers are influenced by the IPs IP1, 2 and 5. The strongest impact is expected in IP5.

Table 4.8 gives an overview of the changes in skills requirements.

Table 4.8Overview of skills impacts of S2R-IPs on logistic engineers: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, reduced risks, reduced responsibilities	ICT; System specifics; simplification	ICT-levels, TCMS	=	=	=
IP2	Less unexpected events/less stress, reduced responsibilities	Simplification, redundancy, x	Technical system	=	=	Rise
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, reduced responsibilities, less noise	Simplification, ICT; System specifics	ICT Control systems	=	=	Rise

The general impact seems to be more predictable work, simplification, improved working conditions and more need for ICT (information and communication technology), but also possible risks of redundancy. This helps explains the reduced need for such logistic engineers in general. The skills profiles however will rise for STEM and organisational skill domains.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the STEM-skills.

Table 4.9 Overview of timing of skills impacts of S2R-IPs on logistics engineers: new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Logistics engineer (ISCO-2)	ICT	IP5: Telematics		IP1: TCMS	IP5 : ATO
	Technical			IP5: Wagon design	
	Traffic	IP5: Operation			IP2: Network IP5: Terminal; propulsion

4.5 Dispatch worker (ISCO-3)

Table 4.10 shows the major TDs that either require a change in skill.

Table 4.10 Overview of S2R-IPs and possible market uptake for dispatch workers and when the (first) impact of the projects are expected.

Code	S2R-TDs	Market uptake
TD1.1	Traction System	2024
TD1.2	TCMS	2023
TD1.6	Doors	2024
TD2.1	Adaptable communications for all railways	2024
TD2.2	Railway network capacity increase	2024
TD2.3	Moving Block	2024
TD2.4	Fail-Safe Train Positioning	2024

Code	S2R-TDs	Market uptake
TD2.8	Virtual-Coupled Train Sets (VCTS)	2024
TD2.9	Traffic management evolution	2024
TD2.10	Smart radio-connected all-in-all	2024
TD2.11	Cyber Security	2024
TD3.1 & 3.2	Switches & Crossings	2024
TD3.3 & 3.4	Track	2021
TD3.5	Bridges & Tunnels	2023
TD3.6-TD 3.8	Intelligent Asset Management (IAM)	2023
TD3.9	Smart Power Supply	2024
TD3.10	Smart Metering Energy	2023
TD3.11	Future (small) stations	2023
TD5.1	Freight electrification & telematics	2021
TD5.2	Access & operation	2021
TD5.3	Wagon Design	2023
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of dispatch workers are influenced by the IPs IP1, 2, 3 and 5. The strongest impact is expected in IP2 and 5.

Table 4.11 gives an overview of the changes in skills requirements.

Table 4.11 Overview of skills impacts of S2R-IPs on dispatch workers: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, changing working hours (night?), less noise, reduced risks, reduced responsibilities, faster actions required (more stress); less time outside train	ICT; System specifics; simplification	ICT-levels, TCMS, Operational knowledge	=	Rise	=
IP2	Less unexpected events/less stress, reduced responsibilities	ICT, System specifics, simplification, redundancy	Communication technology, Technical system, Traffic management, ICT (cyber)	Rise	Rise	Rise
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities	Simplification	ICT, =	=	=	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, reduced responsibilities, less noise	Simplification, ICT; System specifics	ICT Control systems	=	=	Rise

The general impact seems to be less unpredictable work, less responsibilities, more simplification, improved working conditions and more need for ICT (information and communication technology), but also possible risks of redundancy. The skills profiles however will rise in all skill domains.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the STEM-skills.

Table 4.12 Overview of timing of skills impacts of S2R-IPs on dispatch workers: new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Dispatch worker (ISCO-3)	ICT	IP5: Telematics		IP1: TCMS; Modularity IP3: IAM; Smart Metering	IP2: Communication; Smart radio; Cyber; VCTS IP3 : Smart Power IP5 : ATO
	Technical			IP5: Wagon design	IP2: Block; Positioning; Methods
	Traffic	IP3: Track IP5: Operation		IP3: Bridges; Stations	IP1: Traction; Doors IP2: Network; Traffic mgt IP3: Switches & Crossings IP5: propulsion

4.6 Rail maintenance technician; Train maintenance technician (ISCO-3)

Table 4.13 shows the major TDs that either require a change in employment level and/or skill.

Table 4.13 Overview of S2R-TDs and possible market uptake for maintenance technicians and when the (first) impact of the projects are expected.

Code	S2R-TDs	Market uptake
TD1.1	Traction System	2024
TD1.2	TCMS	2023
TD1.3	Car Body	2024
TD1.4	Run Gear	2022
TD1.5	brake	2023
TD1.6	Doors	2024
TD1.7	Modularity	2023
TD2.1	Adaptable communications for all railways	2024
TD2.2	Railway network capacity increase	2024
TD2.3	Moving Block	2024
TD2.4	Fail-Safe Train Positioning	2024
TD2.7	Formal methods and standardisation	2024
TD2.8	Virtual-Coupled Train Sets (VCTS)	2024
TD2.9	Traffic management evolution	2024

Code	S2R-TDs	Market uptake
TD2.10	Smart radio-connected all-in-all	2024
TD2.11	Cyber Security	2024
TD3.1 & 3.2	Switches & Crossings	2024
TD3.3 & 3.4	Track	2021
TD3.5	Bridges & Tunnels	2023
TD3.6-TD 3.8	Intelligent Asset Management (IAM)	2023
TD3.9	Smart Power Supply	2024
TD3.10	Smart Metering Energy	2023
TD3.11	Future (small) stations	2023
TD5.1	Freight electrification & telematics	2021
TD5.3	Wagon Design	2023
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of rail maintenance technicians are influenced by the IPs 1, 2, 3 and 5. The strongest impact is expected in IP1, 2, 3 and 5.

Table 4.14 gives an overview of the changes in skills requirements.

Table 4.14 Overview of skills impacts of S2R-IPs on maintenance technicians: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, changing working hours (night?), less noise reduced risks, reduced responsibilities, prescribed activities faster actions required (more stress); less time outside train	ICT; System specifics; material use, simplification, production process	ICT-levels, TCMS, Materials, Manufacturing, specific, Operational knowledge, ICT	=	Rise	=
IP2.1	Less unexpected events/less stress, reduced responsibilities	ICT, System specifics, simplification, redundancy	Communication technology, Technical system, ICT (cyber)	Rise	Rise	Rise
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities	Simplification	ICT	=	=	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, less noise, reduced responsibilities	Simplification, ICT; System specifics	ICT Control systems	=	=	Rise

The general impact seems to be less unpredictable work, less responsibilities, more simplification, improved working conditions and more need for ICT (information and communication technology), but also possible risks of redundancy. The skills profiles however will rise in all skill domains.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the STEM-skills.

Table 4.15 Overview of timing of skills impacts of S2R-IPs on rail maintenance technicians; train maintenance technicians: new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Rail maintenance technician; Train maintenance technician (ISCO-3)	ICT	IP5: Telematics		IP1: TCMS; Modularity IP3: IAM; Smart Metering	IP2: Communication; Smart radio; Cyber; VCTS IP3 : Smart Power IP5 : ATO
	Technical			IP5: Wagon design	IP2: Block; Positioning; Methods
	Traffic	IP3: Track	IP1: Run gear	IP1: Brake IP3: Bridges; Stations	IP1: Traction; Body; Doors IP2: Network; Traffic mgt IP3: Switches & Crossings IP5: propulsion

4.7 Rail logistics coordinator (ISCO-4)

Table 4.16 shows the major TDs that either require a change in skill.

Table 4.16 Overview of S2R-TDs and possible market uptake for rail logistics coordinators and when the (first) impact of the projects are expected.

Code	S2R-TDs	Market uptake
TD1.2	TCMS	2023
TD1.6	Doors	2024
TD2.1	Adaptable communications for all railways	2024
TD2.2	Railway network capacity increase	2024
TD2.3	Moving Block	2024
TD2.4	Fail-Safe Train Positioning	2024
TD2.8	Virtual-Coupled Train Sets (VCTS)	2024
TD2.9	Traffic management evolution	2024
TD2.10	Smart radio-connected all-in-all	2024
TD2.11	Cyber Security	2024
TD3.1 & 3.2	Switches & Crossings	2024
TD3.3 & 3.4	Track	2021
TD3.5	Bridges & Tunnels	2023
TD3.6-TD 3.8	Intelligent Asset Management (IAM)	2023
TD3.9	Smart Power Supply	2024
TD3.10	Smart Metering Energy	2023
TD3.11	Future (small) stations	2023
TD5.1	Freight electrification & telematics	2021

Code	S2R-TDs	Market uptake
TD5.2	Access & operation	2021
TD5.3	Wagon Design	2023
TD5.4	Novel Terminal	2024
TD5.5	Propulsion	2024
TD5.6	Autonomous Train Operation	2024

The tasks of the rail logistics coordinator are influenced by the IPs IP1, 2, 3 and 5. The strongest impact is expected in IP2 and 5, although with limited total impact.

Table 4.17 gives an overview of the changes in skills requirements.

Table 4.17 Overview of skills impacts of S2R-TDs on rail logistics coordinators: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, reduced risks, reduced responsibilities, faster actions required (more stress); less time outside train	ICT; system specifics; simplification	ICT-levels, TCMS, operational knowledge	=	Rise	=
IP2	<>, Less unexpected events/less stress, reduced responsibilities	ICT, system specifics, simplification, redundancy	Communication technology, Technical system, Traffic management, ICT (cyber)	Rise	Rise	Rise
IP3	Prescribed activities, less unexpected events/less stress	Simplification	ICT	=	=	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, reduced responsibilities, less noise	Simplification, ICT; system specifics	ICT control systems	=	=	Rise

The general impact seems to be less unpredictable work, less responsibilities, more simplification, improved working conditions and more need for ICT (information and communication technology), but also possible risks of redundancy. The skills profiles however will rise in all skill domains.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the STEM-skills.

Table 4.18 Overview of timing of skills impacts of S2R-IPs on rail logistics coordinators: new ICT, technical and traffic competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Rail logistics coordinator (ISCO-4)	ICT	IP5: Telematics		IP1: TCMS IP3: IAM; Smart Metering	IP2: Communication; Smart radio; Cyber IP3 : Smart Power IP5 : Terminal ; ATO
	Technical			IP5: Wagon design	IP2: Block; Positioning
	Traffic	IP3: Track IP5: Operation		IP3: Bridges; Stations	IP1: Doors IP2: Network; Traffic mgt IP3: Switches & Crossings IP5: propulsion

4.8 Train attendant (ISCO-5)

Table 4.19 shows the major TDs that either require a change in skill.

Table 4.19 Overview of S2R-IPs and possible market uptake for train attendants and when the (first) impact of the projects are expected.

Code	S2R-IPs	Market uptake
IP1.6	Doors	2024
IP2.10	Smart radio-connected all-in-all	2024
IP3.1 & 3.2	Switches & Crossings	2024
IP3.3 & 3.4	Track	2021
IP3.5	Bridges & Tunnels	2023
IP3.6-IP 3.8	Intelligent Asset Management (IAM)	2023
IP3.9	Smart Power Supply	2024
IP3.10	Smart Metering Energy	2023
IP3.11	Future (small) stations	2023
IP4.1	interoperability framework	2024
IP4.2	Travel Shopping	2022
IP4.3	booking & ticketing	2022
IP4.4	Trip Tracker	2022
IP4.5	Travel Companion	2022
IP4.6	Business Analytics Platform	2022
IP4.7	Overall IP4 Coordination and demonstration	2021

The tasks of train attendants are influenced by the IPs IP1, 2, 3 and 4. The strongest impact is expected in IP1.

Table 4.20 gives an overview of the changes in skills requirements.

Table 4.21 Overview of skills impacts of S2R-IPs on train attendants: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Faster actions required (more stress); less time outside train, reduced risks, reduced responsibilities	Simplification	Operational knowledge	=	Rise	=
IP2	Less unexpected events/less stress		Communication technology	Rise	=	=
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities	Simplification	ICT	=	=	=
IP4	More challenging questions, supported by ICT tools, less stress from unhappy customers, increased labour satisfaction	ICT tool usage	ICT	=	Rise	Rise

The general impact seems to be more predictable work, simplification, improved working conditions and more need for ICT (information and communication technology). The skills profiles however will rise in all skill domains.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the ICT-skills. The following table lists the estimated earliest date for the ICT-skills.

Table 4.22 Overview of timing of skills impacts of S2R-IPs on train attendants: new ICT competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Train attendant (ISCO-5)	ICT		IP4: business analytics	IP3: IAM; Smart metering	IP2: Smart radio IP4: interoperability
	Simplification	IP3: Track	IP4	IP3: Track; Bridges; Stations	IP1: Doors IP3: Switches & Crossings

4.9 Train driver (ISCO-8)

Table 4.23 shows the major TDs that either require a change in skill. For the impact on employment, it is also needed to understand if automatic driving may make this occupation obsolete[2]. Our analysis does not take a full automation into account.

[2] Automated Train Operation is only foreseeable if ERTMS is implemented. ERTMS is only in the beginning phases in the different countries. With ERTMS, levels 3 (driving without train driver) and 4 (driving without personnel on board) of ATO could be possible. Such scenarios are not foreseeable on the short term: level 2 (automatic driving with a train driver) is more likely.

Table 4.23 Overview of S2R-IPs and possible market uptake for train drivers and when the (first) impact of the projects are expected.

Code	S2R-IPs	Market uptake
IP1.2	TCMS	2023
IP1.5	Brake	2023
IP2.1	Adaptable communications for all railways	2024
IP2.2	Railway network capacity increase	2024
IP2.3	Moving Block	2024
IP2.4	Fail-Safe Train Positioning	2024
IP2.7	Formal methods and standardisation	2024
IP2.8	Virtual-Coupled Train Sets (VCTS)	2024
IP2.9	Traffic management evolution	2024
IP2.10	Smart radio-connected all-in-all	2024
IP2.11	Cyber Security	2024
IP3.1 & 3.2	Switches & Crossings	2024
IP3.3 & 3.4	Track	2021
IP3.5	Bridges & Tunnels	2023
IP3.6-IP 3.8	Intelligent Asset Management (IAM)	2023
IP3.9	Smart Power Supply	2024
IP3.10	Smart Metering Energy	2023
IP3.11	Future (small) stations	2023
IP5.1	Freight electrification & telematics	2021
IP5.2	Access & operation	2021
IP5.3	Wagon Design	2023
IP5.4	Novel Terminal	2024
IP5.5	Propulsion	2024
IP5.6	Autonomous Train Operation	2024

The tasks of train drivers are influenced by the IPs IP1, 2, 3 and 5. The strongest impact is expected in IP2 and 5.

Table 4.24 gives an overview of the changes in skills requirements.

Table 4.24 Overview of skills impacts of S2R-IPs on train drivers: conditions, task environment, STEM, communication (COMM), social (SOC) and organisational (ORG) skills (=: no change)

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP1	Less unexpected events, less stress, reduced risks, reduced responsibilities	ICT; System specifics; simplification	ICT-levels, TCMS, specific	=	=	=
IP2	Less unexpected events/less stress, reduced responsibilities, prescribed activities	ICT, System specifics, simplification, redundancy	Communication technology, Technical system, Traffic management, ICT (cyber)	Rise	Rise	Rise

IP	Aggregation of conditions change	Aggregation of task change	STEM	COMM	SOC	ORG
IP3	Prescribed activities, less unexpected events/less stress, reduced responsibilities, prescribed activities	Simplification	ICT	=	=	=
IP5	Prescribed activities, less unexpected events/less stress, less polluted working environment, reduced responsibilities	Simplification, ICT; System specifics	=	=	=	=

The general impact seems to be more predictable work, simplification, improved working conditions and more need for ICT (information and communication technology), but also possible risks of redundancy. The skills profiles however will rise in all skill domains. This is unexpected.

When will these changes occur at the earliest date? As explained for managers, we will focus on the timing of the STEM-skills. The following table lists the estimated earliest date for the ICT-skills.

Table 4.25 Overview of timing of skills impacts of S2R-IPs on train drivers: new ICT competences.

Rail occupation	New STEM-requirements	2021	2022	2023	2024
Train driver (ISCO-7)	ICT			IP3: IAM; Smart Metering	IP2: Smart Radio IP3: Smart Power IP4: Interoperability
	simplification	IP4: coordination and demonstration	IP4	IP3: Track; Bridges; Stations	IP1 IP3: Switches & Crossings

4.10 Skill changes along the entire rail value chain

The rail value chain is conceived as four critical actors in the support of the rail sector: manufacturers (components, train manufacturers), system integrators, train operators (freight, passenger) and infrastructure managers. The innovation activities in the five IPs are conducted in cooperation with all these actors. This means that all IPs will impact these actors. The eight occupations analysed in this report mainly show the changes for the train operators (all occupations) and the infrastructure managers (mainly: rail operations manager, engineer (mechanical, electrical, ICT) and rail maintenance technician). The conclusions for these occupations can be included in the impacts on these parts of the rail value chain. For the skills impacts, the focus is mainly on the ICT, technical and transport skills these actors will experience.

4.10.1 Manufacturers

Manufacturers are crucial for the delivery of most of the new components and trains for the future performance of the rail sector. They will be responsible for the computer technologies that are integrated into components and trains. They will be responsible for developing new technologies using these technologies and for offering sustainable solutions. This means that they will need to continue to invest in the following skill areas for their developers, manufacturing specialists and integrators:

- IP1. Cost-efficient and reliable trains, including high-capacity trains and high-speed trains: this IP will be central for the manufacturers of components and trains. They will need to invest into improving their knowledge about information technology and mechanical and electrical engineering to allow to build new control systems, measurement systems (monitoring and data collection, analysis) and to understand how to create autonomous train operation. The leading manufacturers (Bombardier, Alstom, Siemens) are already world leaders in these domains.
- IP2. Advanced Traffic Management and Control Systems: for this IP, information technology specialists will be engaged to deliver the required information and communication technologies for the operators to be able to manage and maintain the infrastructure. The main skill requirement for these IT specialists will be to have an understanding of the specific environment of the rail systems and operations, and creation IT-safe and reliable systems.
- IP3. Cost-Efficient and Reliable High-Capacity Infrastructure: for this IP, information technology specialists will be engaged to deliver the required information and communication technologies for the operators to be able to manage and maintain the infrastructure. The main skill requirement for these IT specialists will be to have an understanding of the specific environment of the rail systems and operations.
- IP4. IT Solutions for Attractive Railway Services: for this IP, mainly component manufacturers will play a role in delivering tools to support the integration of different transportation modes. Information technology specialists will be engaged to deliver the required information and communication technologies for the operators to be able to conduct their required analytics. The main skill requirement for these (component) manufacturers will be to have an understanding of the specific environment of the rail systems and operations.
- IP5. Technologies for Sustainable & Attractive European Rail Freight: this IP will be the second central task for the manufacturers of components and trains. They will need to invest into improving their knowledge about information technology (telematics, ATO) and mechanical and electrical engineering to allow to build new trains and new freight propulsion concepts. The leading manufacturers (Bombardier, Alstom, Siemens) are already world leaders in these domains.

The fact that manufacturers supply the other parts of the value chain the main technologies, means that they need to have the technology lead in all of these IPs. For these companies, it requires them to tap into the leading knowledge in ICT and all engineering domains. This knowledge needs to be necessarily at the highest level (academic) to be able to understand the detailed operation of all the parts, but also to understand the integration of all the parts. The manufacturers need to be able to understand the requirements from the other parts of the value chain to deliver the right and sustainable solutions for the future.

4.10.2 System integrators

As the manufacturers, system integrators are equally crucial for the integration of most solutions to the operators and infrastructure managers of the rail sector. In cooperation with the manufacturers, they will be responsible for the computer technologies that are integrated into components and trains. This means that they will need to continue to invest in the following skill areas for their developers, integration specialists and planners:

- IP1. Cost-efficient and reliable trains, including high-capacity trains and high-speed trains: the systems integrators will not be the builders or developers of these technologies. Their role will be to co-develop the requirements for these trains. System integrators will need to have an in-depth understanding of the control systems, ATO and data requirements. They will also require an understanding of the mechanical and electrical engineering of these trains to be able to integrate new train systems into their solutions. In contrast to the manufacturers, the system integrators need to have an understanding of current train systems (and different vintages of trains) and to see how all of these vintages can seamlessly work together. System integrators will need to manage these different knowledge traditions, more so than any actor in the rail value chain.

- IP2. Advanced Traffic Management and Control Systems: as for IP1, system integrators will need to have an understanding of current and past Traffic Management and Control Systems. They will need state-of-the-art understanding of the communication and information systems, management and operational management to be able to integrate all technologies into a workable rail system.
- IP3. Cost-Efficient and Reliable High-Capacity Infrastructure: the requirements are much in line with what has been said about IP2: system integrators need to have in-depth ICT and management knowledge, now focused on the infrastructure system.
- IP4. IT Solutions for Attractive Railway Services: again, system integrators will also need to have an in-depth understanding of railway services. They will probably not be developing solutions for these services themselves, but any systems integration will need to support railway services in all its dimensions. For system integrators, they need to work with the operators for this understanding.
- IP5. Technologies for Sustainable & Attractive European Rail Freight: all of the above applies for the systems integration in the freight domain. System integrators will require academic level knowledge of ICT, management and operation of freight systems. They will need to work with freight operators, next to passenger operators to develop sustainable system solutions.

The manufacturers need to have the technology lead in all of these IPs, but system integrators need to have their part in any development of these IPs. System integrators need to have access to leading knowledge in ICT and all engineering domains. This knowledge needs to be necessarily at the highest level (academic) to be able to understand the detailed operation of all the parts, but also to understand the integration of all the parts. As for manufacturers, system integrators need to be able to understand the requirements from the other parts of the value chain to deliver the right and sustainable solutions for the future.

4.10.3 Train operators

For train operators (passenger and freight), the current report describes in detail the requirements and changes in requirements for the main eight occupations. These requirements will not further be discussed here. Of importance is however the ability of the train operators to be able to formulate the requirements for manufacturers, system integrators and infrastructure managers. This will put extra requirements on managers, engineers and planning functions with the train operators. There are no real differences to be expected for passenger and freight transport: both will need to further develop this capability at the academic level.

4.10.4 Infrastructure managers

As indicated, the current report gives an overview of the changed skills requirements for central occupations among infrastructure managers: rail operations manager, engineer (mechanical, electrical, ICT) and rail maintenance technician. The overviews show which STEM-skills will be required in the future and when. Next to these requirements, infrastructure managers will, as this is the case for the operators, be able to formulate the right requirements for the other actors in the rail value chain. Mainly because these actors are not integrated into their role in the system, the infrastructure managers need to be able to formulate sustainable and understandable requirements. This requires the right roles among infrastructure managers and an academic level understanding of the operation of the whole value chain.

4.10.5 Overview changing skills in the rail value chain

In table 4.26, we have summarised the possible skills impact on the rail value chain. We make the distinction between management, development and manufacturing positions in these parts of the value chain and, if available from this current study, position the results from the occupations analysed in this report, in this table. The analysis gives an overview of the possible skill domains that will be most affected by the S2R R&I and which direction this will be. Also, we indicate possible skill issues that may play a role.

Table 4.26 Overview of skill gaps rising through S2R-IPs

Main roles	Example rail occupation from this report	New STEM/ICT requirements	Issues
		Manufacturers	
Management	Rail operations manager (ISCO-1)	› understand the requirements from the other parts of the value chain › manage the technology lead in all of these IPs › tap into the leading knowledge in ICT and all engineering domains.	Shift to academic level
Developers	Engineer (mechanical, electrical, ICT) (ISCO-2)	› control systems › measurement systems (monitoring and data collection, analysis) › autonomous train operation › manage and maintain the infrastructure › understanding of the specific environment of the rail systems and operations › creation IT-safe and reliable systems. › support the integration of different transportation modes › deliver the required information and communication technologies › telematics › build new trains and new freight propulsion concepts	Shift to academic level
Manu-facturing	Rail maintenance technician; Train maintenance technician (ISCO-3)	› In line with developers, but then the manufacturing side.	Skills levels to higher professional and bachelor levels
System integrators			
Management	Rail operations manager (ISCO-1)	› understand the detailed operation of all the parts › understand the integration of all the parts and the requirements from the other parts of the value chain; collaborative skills › co-develop the requirements for these trains	Shift to academic level
Developers	Engineer (mechanical, electrical, ICT) (ISCO-2)	› control systems › ATO › data requirements › understanding of the mechanical and electrical engineering of these trains › understanding of current train systems (and different vintages of trains) › understanding of current and past Traffic Management and Control Systems	Shift to academic level Ability to master different vintages of technology

Main roles	Example rail occupation from this report	New STEM/ICT requirements	Issues
		› understanding of the communication and information systems, management and operational management › in-depth ICT and management knowledge on the infrastructure system. › in-depth understanding of railway services	
Planners, integration specialists	Logistics engineer (ISCO-2) Dispatch worker (ISCO-3)	› understand the detailed operation of all the parts › understand the integration of all the parts and the requirements from the other parts of the value chain; collaborative skills › understanding control systems, ATO, data requirements › understanding of current and past Traffic Management and Control Systems › in-depth ICT and management knowledge on the infrastructure system. › in-depth understanding of railway services	Skills levels to higher professional and bachelor levels
Train operators			
Management	Rail operations manager (ISCO-1)	› See table 5.1 › ability of the train operators to be able to formulate the requirements for manufacturers, system integrators and infrastructure managers	See table 5.1
Developers	Engineer (mechanical, electrical, ICT) (ISCO-2)	See table 5.1	See table 5.1
Planning	Logistics engineer (ISCO-2)	See table 5.1	See table 5.1
	Dispatch worker (ISCO-3)	See table 5.1	See table 5.1
	Rail logistics coordinator (ISCO-4)	See table 5.1	See table 5.1
Maintenance	Rail maintenance technician; Train maintenance technician (ISCO-3)	See table 5.1	See table 5.1
Operation	Train attendant (ISCO-5)	See table 5.1	See table 5.1
	Train driver (ISCO-7)	See table 5.1	See table 5.1
Infrastructure manager			
Management	Rail operations manager (ISCO-1)	› See table 5.1 › ability of the train operators to be able to formulate the requirements for manufacturers, system integrators and train operators	Shift to academic level
Planning	Logistics engineer (ISCO-2)	See table 5.1	See table 5.1
	Dispatch worker (ISCO-3)	See table 5.1	See table 5.1
	Rail logistics coordinator (ISCO-4)	See table 5.1	See table 5.1

Main roles	Example rail occupation from this report	New STEM/ICT requirements	Issues
Maintenance	Rail maintenance technician; Train maintenance technician (ISCO-3)	See table 5.1	See table 5.1

5 Result 3: Identifying the skill gaps

To identify potential skill gaps, the results from the analysis in Chapter 4 are compared to the main result from report D1a. In this first D1a report, an overview was given of the current skill levels present among the job holders. The report identified the current technical skill level using the International Standard Classification of Education (ISCED 1-6[3]), the available STEM, communication, social and organisational skills. The analysis in Chapter 4 has put forward new skill requirements for the occupations. In the comparison with the D1a report, we look at the requirements in the previous tables and align them with the current skill levels as identified in D1a. Higher STEM, communication, social and organisational skills are foreseen in the previous tables. This rule has been applied in Table 5.1. The last colon identifies the main skill gaps for each of the occupations.

Table 5.1Overview of skill gaps rising through S2R-IPs

Rail occupation	Current skill level	New requirements	Gaps
Rail operations manager (ISCO-1)	Technical: ISCED 3-6 STEM: high COMM: high SOC: low ORG: high	Technical: ISCED 5-6 STEM: ICT, technical, traffic COMM: high SOC: high ORG: high	Mainly more ICT, technical and traffic management skills SOC skills need to be developed
Engineer (mechanical, electrical, ICT) (ISCO-2)	Technical: ISCED 5-6 STEM: high COMM: high SOC: low ORG: high	Technical: ISCED 5-6 STEM: ICT, technical, traffic COMM: high SOC: high ORG: high	Skill levels are already high, but more ICT skills needed SOC skills need to be developed
Logistics engineer (ISCO-2)	Technical: ISCED 5-6 STEM: high COMM: high SOC: low ORG: high	Technical: ISCED 5-6 STEM: ICT, technical, traffic COMM: high SOC: low ORG: high	Skill levels are already high, but more ICT skills needed
Dispatch worker (ISCO-3)	Technical: ISCED 5-6 STEM: medium COMM: medium SOC: medium ORG: medium	Technical: ISCED 5-6 STEM: ICT, technical, traffic COMM: high SOC: high ORG: high	Skill levels are already high, but more ICT skills needed All skills need to be developed
Rail maintenance technician; Train maintenance technician (ISCO-3)	Technical: ISCED 5-6 STEM: medium COMM: medium SOC: medium ORG: medium	Technical: ISCED 5-6 STEM: ICT, technical, traffic COMM: high SOC: high ORG: high	Skill levels are already high, but more ICT skills needed All skills need to be developed
Rail logistics coordinator (ISCO-4)	Technical: ISCED 3-4 STEM: medium COMM: medium SOC: medium ORG: medium	Technical: ISCED 3-6 STEM: ICT, technical, traffic COMM: high SOC: high ORG: high	Mainly more ICT, technical and traffic management skills All skills need to be developed

[3] ISCED levels of education: 0 = pre-primary education; 1 = primary education; 2 = lower secondary education; 3 = upper secondary education; 4 = post-secondary non-tertiary education (professional level); 5 = first stage of tertiary education (bachelor); 6 – second stage of tertiary education (masters; PhD).

Rail occupation	Current skill level	New requirements	Gaps
Train attendant (ISCO-5)	Technical: ISCED 3-6 STEM: medium COMM: medium SOC: medium ORG: medium	Technical: ISCED 3-6 STEM: ICT, simplification COMM: high SOC: high ORG: high	More ICT, less technical skills All skills need to be developed
Train driver (ISCO-7)	Technical: ISCED 3-6 STEM: medium COMM: low SOC: low ORG: medium	Technical: ISCED 3-6 STEM: ICT, simplification COMM: medium SOC: medium ORG: medium	More ICT, less technical skills All skills need to be developed

The skill gaps in table 5.1 show that all occupations will require different degrees of ICT and specific technical skills. This requirement seems to be there, even if the IPs also lead to more simplification of work and less responsibilities. The train driver job is the only listed occupation in which the STEM and other skills remain at a medium level. It seems that technical change mainly leads to simplification of the tasks in these train driver's jobs (in the case ATO-level 2 may get implemented: automated driving with presence of train driver). All other jobs seem to require high levels of these skills.

6 Conclusions and remaining points for discussion

6.1 Conclusions

This report summarizes the main analysis of the impact of the IPs supported by S2R on skills in the railway sector. In the report, we have looked at the general impacts and for the more specific impacts, we have looked at changes in requirements for eight typical rail occupations. The following conclusions can be deduced from the analysis in this report:

- In terms of skill changes, all job categories show a shift in the need for more ICT and (broad) technical skills. All job categories except train drivers show a shift in all types of skills to higher levels (academic, engineering level). In this sense, all occupations except train drivers show skill gaps that will need to be addressed by the railway organisations in the future years.
- The impacts have been calculated over a period of 2 to 6 years. The development seems to start with strong impacts at the beginning of this period and at the end of the period under observation.

6.2 Questions for further analysis

The following further analyses are needed:

- In this report, we have listed a broad set of assumptions for estimating impacts of IPs on employment and skills. Future analyses need to focus on collecting likely alternatives for these assumptions. These alternatives will lead to even more change scenarios for the employment in the sector.
- The estimations have been made for a small selection of occupations in the sector. Future studies need to add other occupations. For the selection of other jobs, we suggest that researchers strive to be attentive to the distribution of jobs according to ISCO-levels. The spread in ISCO-levels remains important to understand different schooling and employment practices connected to these ISCO-levels.
- For the estimations, this report relies on the expertise of a limited set of experts. The technical experts developing the S2R-technologies should be included in further projects. More time is needed to complete such interviews and assessments. For the current S2R-projects, project leaders are required to make cost impacts of their innovations. Project leaders should also consider the employment impact of their innovations. This is not yet a standard practice.
- This report does not consider differences between countries. The impacts will be very different between countries, mainly because of the differences in composition of the rail systems. Technologies will have different impacts, and the aggregated impact at the country level will necessarily be different between countries.
- A last issue is that we assume that all railway companies use the same organisational models. This is clearly not the case, but the impact of the models on the use and development of technologies is not clear from this study. This would require a separate study in itself.

The current report has been discussed with stakeholders in the railway sector. Results are taken up in report D3b. This discussion adds more understanding of the impact of the assumptions used in this report.

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Annex 1 Overview of S2R IPs and TDs

IP/TD		TD measure/characteristics
IP1 - Cost-efficient and reliable trains, including high-capacity trains and high-speed trains		
TD1.1	Traction System	Production, availability and smart maintenance
		Low noise
		Brakes low adhesion management
TD1.2	TCMS	TCMS availability, maintenance
		TCMS operation and coupling time & ability
		TCMS production & implementation
TD1.3	Car Body	Modular structures and new materials
		Improved manufacturing technologies
		Less weight
TD1.4	Run Gear	Less weight
		Improved curving
		Standardised sensor system maintenance
TD1.5	Brake	Brake diagnostics/monitoring
		Shorter brake distance/friction pair solutions
		Reduced system complexity
TD1.6	Doors	Modular and less weight
		Autonomous, passenger detection
		Faster and increased capacity/minute
TD1.7	Modularity	Modularity/plug and play
IP2 - Advanced Traffic Management and Control Systems		
TD2.1	Adaptable communications for all railways	Using standard components, satellite communication in
		Urban areas, standardised functions &interfaces
		Alternative communication paths
		Sharing communication network, use public network
TD2.2	Railway network capacity increase (ATO up to GoA4 – UTO)	HS, Regional, Urban
TD2.3	Moving Block	Decoupling signaling from infra., and not designed for worst case trains
		Removal trackside assets and interlocking interfaces
		On-Board assets for safe train positioning and train integrity proof
TD2.4	Fail-Safe Train Positioning	Selecting tracks
		Decoupling signaling from infra., and not designed for worst case trains
		Removal trackside assets and interlocking interfaces
		On-Board assets of safe train positioning and train integrity proof
TD2.5	On-board Train Integrity	Decoupling signaling from infra., and not designed for worst case trains
		Removal trackside assets and interlocking interfaces
		On-Board assets of safe train positioning and train integrity proof
TD2.6	Zero on-site testing	Reduction of testing time and resources

IP/TD		TD measure/characteristics
TD2.7	Formal methods and standardisation for smart signalling systems	Reduction of project/country specific
		Development by different competitors
		Standardised Interfaces
TD2.8	Virtual-Coupled Train Sets (VCTS)	Increasing of (virtual) train length
		Individual platform usage independent from length
		Removal trackside assets
TD2.9	Traffic management evolution	New functional service modules
		Computer assisted disposition
		Intelligent Driver Assistance System
		Standardisation of frameworks, data structures and interfaces
TD2.10	Smart radio-connected all-in-all wayside objects	Reduction of cable failures & theft
		Removal of cables from the interlocking system to the wayside assets
TD2.11	Cyber Security	More robust and controlled network
		Management of cryptographic information
		Standardisation of design methods, interfaces, architecture and protocol
IP3 - Cost-Efficient and Reliable High-Capacity Infrastructure		
TD3.1 & 3.2	Switches & Crossings	More efficient maintenance execution
		Reduced maintenance
		Reduced failure events/faults
		Improved design
TD3.3 & 3.4	Track	More efficient maintenance execution
		Reduced maintenance
		Reduced failure events/faults
		Improved design
TD3.5	Bridges & Tunnels	More efficient maintenance execution
		Predictive maintenance
		Improved design, including upgrading and life extension
TD3.6-TD3.8	Intelligent Asset Management(IAM)	Optimised working methods
		Decision support tools
		Monitoring capabilities
		Predictive maintenance, maintenance data
TD3.9	Smart Power Supply	Improved operation by more efficient control and monitoring
		Higher capacity with less redundancy for traction power supply
		Energy optimised power network
		Optimised Interface at infeed point
TD3.10	Smart Metering Energy	Monitoring capabilities
		Improved design, avoid over dimensioning
TD3.11	Future (small) stations	Enhanced S&C sub-system and component design
		Improved design of platforms and close-by areas

IP/TD		TD measure/characteristics
IP4 - IT Solutions for Attractive Railway Services		
TD4.1	Interoperability framework	Advanced product portfolio
TD4.2	Travel Shopping	Customised travel offers
		One-stop-shopping
		Inter-/multi-/transmodal travel offers
		Single ticketing
TD4.3	Booking & ticketing	Harmonisation of rights to travel
		Intermodal travel offers
		Security
TD4.4	Trip Tracker	Personalised journey information
		Booking & ticketing usability
		Customised recommendations
		One-stop shopping
TD4.5	Travel Companion	Employer attractiveness
		Intermodal travel offers
		Booking & ticketing usability
TD4.6	Business Analytics Platform	Employer attractiveness
		Intermodal travel offers
		Quality of services
TD4.7	Overall IP4 Coordination and demonstration	Employer attractiveness
IP5 - Technologies for Sustainable & Attractive European Rail Freight		
TD5.1	Freight electrification & telematics	Condition based maintenance
		Automatic coupling
		Telematics and electrification
TD5.2	Access & operation	Improved method for timetable planning
		Real-time network management
		Increased speed of freight trains during day time traffic
		Real-time yard management
TD5.3	Wagon Design	Core market and extended market wagon 2020
		Low noise, lightweight, high speed & track
		Friendly running gear
TD5.4	Novel Terminal	Intelligent video gate terminal (ID check of wagons)
		Hybridisation of shunting locomotives
TD5.5	Propulsion	Freight loco of the future
		Long trains up to 1500 m
		Full electric last mile propulsion system
TD5.6	Autonomous Train Operation	

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