Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains – Phase 2

Deliverable D 8.4
Final Skills and qualifications and creating agile organizations (final report)

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### Abbreviations and acronyms

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<td>ATO</td>
<td>Automatic Train Operation</td>
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<tr>
<td>CA</td>
<td>Collaboration Agreement</td>
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<td>CMT</td>
<td>Crisis Management team</td>
</tr>
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<td>DMP</td>
<td>Data Management Plan</td>
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<td>DoA</td>
<td>Description of Action</td>
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<td>Grant Agreement</td>
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<td>IMPACT-2</td>
<td>Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains – Phase 2</td>
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<td>IV</td>
<td>Information Vonlunteers (in French: VI means “Volontaires de l’Information”)</td>
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<tr>
<td>IP</td>
<td>Innovation Programme</td>
</tr>
<tr>
<td>JU</td>
<td>Joint Undertaking</td>
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<tr>
<td>MRC</td>
<td>Mobile Railway Crew (in French: EML means “Equipe Mobile de Ligne”)</td>
</tr>
<tr>
<td>PM</td>
<td>Project Manager (coordinator)</td>
</tr>
<tr>
<td>RAT</td>
<td>Rapid Assistance Team (in French: EAR means “Equipe d’Action Rapide”)</td>
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<td>S2R</td>
<td>Shift2Rail</td>
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<tr>
<td>SNCF</td>
<td>The French railway company (in French: “Société Nationale des Chemins de Fer”)</td>
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<tr>
<td>SPD</td>
<td>System Platform Demonstrator</td>
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<tr>
<td>TD</td>
<td>Technology Demonstrator</td>
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<td>TMT</td>
<td>Technical Management Team</td>
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<td>UTO</td>
<td>Unattended Train Operation</td>
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<td>WP</td>
<td>Work Package</td>
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1 Executive summary

This document provides the main conclusions of the IMPACT-2 Work Package (WP) 8 “Human Capital” regarding the research topics "agile organizations" and "skills and qualifications".

First, a qualitative investigation of the creation and the story of an agile organization is presented. This study concerns a crisis management team (CMT) that has been set up in France at SNCF to make the company more agile in the face of railway incidents that cause passenger flow management problems. From the crisis management literature, the sociology of professions and an in-depth ethnography, this study investigates the professionalization and de-professionalization of the CMT through its story of success and failure. Core findings reveal three key episodes from the creation of the CMT to its decline. For each of these phases, the data show how organizational and professional logics can support or hinder each other. The balance between normal and agile organization always appears delicate to find and maintain. Results question the relevance of integrating crisis management as a profession in railway organizations and highlight the difficulty to maintain agility within “bureaucratic” organization. It finally provides some practical outcomes by comparing the agility of two models (professional group model vs. expert network model) in managing crises.

Then, a quantitative investigation of the future development of skills and qualifications is presented. Due to the many variables that need to be taken into account in such an assessment (e.g. long-term investment planning), the study has been limited to the Swedish railway industry and the part of the sector related to infrastructure for which detailed employment data was available. This part of the investigation focuses on the influence on human capital from innovations in Shift2Rail Innovation Programme 3 (IP3). Results indicate that IP3 will have an overall impact at system level (e.g. increased productivity enabled by improved long-term maintenance planning and operation) rather than affecting specific professional roles. In contrast, the impact of the technological development of Shift2Rail IP2 and IP5 is anticipated to affect specific operational jobs (e.g. train drivers, train attendees, train operations managers, etc.) both with respect to employment levels and skills requirements. The study has shown a research method for assessing the impact of technological development on the labor market which combines detailed knowledge of the current situation in the sector, numerical predictions and in-depth interviews with expert representatives from the sector. It is proposed for future work to apply this methodology to investigate the part of the railway sector related to traffic.

In both studies, a bottom-up approach was adopted, leading to a precise view on a limited scope, and allowing quantitative analyses to be carried out where useful. However, this approach inherently lacks conclusions regarding the global railway sector: the key points identified shall then be confirmed and applied at a wider scope to build the global picture.
2 Background

The present document constitutes the Deliverable D8.4 “Skills and Qualification and Creating Agile Organizations” in the framework of the Work-package 8 of the project IMPACT-2 and of the Work Area 6 “Human Capital of the Cross-Cutting Activities (CCAs).

The overall objective of “Human Capital” is to bridge the gap between the massive changes in the railway and other industrial sectors imposed by rapid technological advances and the substantial demographic change in the “Human Capital” expected in the near future. In particular, the activities should contribute to overcome the challenges imposed by demographic change and to balance the benefits and risks for the human capital imposed by comprehensive and radical technological innovations. Hence several research topics in the area of human capital have been identified as of paramount interest for the success and pertinence of the Shift2rail initiative:

- Changes in job profiles (task 8.1)
- Skills and qualifications (task 8.2)
- Agile organizations (task 8.3)
- Customer-oriented design of mobility (task 8.4)

This document, deliverable D8.4, synthetizes the work carried out in tasks 8.2 (skills and qualifications) and 8.3 (agile organizations).

The conclusions reached at this stage of the R&I regarding the two other tasks, i.e. "required changes in job profiles" and "new needs in the design of mobility to fit with customers future expectations" are provided in deliverable D8.3.
3 Objectives/aims

3.1 Objectives and aims of the first study: Creating (and sustaining) agile railway organizations

Initial Expectation of task 8.3: The point stressed the importance of creating agile organizations to deal with unforeseen and indeterminate events. Emphasis was placed on the need to design organizations that are flexible enough to adapt to crises to ensure security.

Focal point task 8.4 – part regarding agile organization: Our work is primarily driven by the expectation of results in terms of organizations used to managing crisis situations: their characteristics, lessons learned, competencies, learning and portability.

Approach: To investigate agile organizations, we explored the eight-year story (2009–2017) of a new crisis management team (EAR), created in the SNCF to manage human flow crisis. The choice to focus on this team was motivated by its reputation as the most agile team in the company. But upon closer investigation of these crisis management team, we realized that the agility of the early days had been eroded over time. We therefore sought to understand how this team had built up its crisis management agility in the first instance, and how it had lost it in the second instance.

Outputs: To understand this surprising process, we draw upon the sociology of professions and the crisis management literatures. We analyzed the agile phase of the team as a professionalization phase, and the non-agile phase of the team as a de-professionalization phase. By analyzing each of these phases, we described how crisis management professionalization mechanisms can paradoxically lead to crisis management de-professionalization mechanisms, with some organizational benefits (increase in the level of knowledge of crisis management within the company) but also with human costs (decrease in motivation and loss of meaning within the team). In other words, we try to explain how and why a team that was initially particularly effective in crisis management found itself, despite itself, unable to manage them.

3.2 Objectives and aims of the second study: Future skills and qualifications in the railway sector

Initial Expectation of task 8.2: The railway system is experiencing a wave of technological modernization. Digitalization will introduce new tools and working methods affecting all segments of the railway sector, from the building and maintenance of infrastructure and vehicles to the monitoring and asset management performed by infrastructure managers and operators. The development of automatic train operations and smart algorithms for traffic management will further influence rail transport in the future. Against this background, the current work is purposed to investigate how this technological development will affect the skills and competence needs of personnel active in the industry. A quantitative and qualitative prognosis of the development with respect skills at a 5- and 10-years perspective is to be presented.

Approach: To make a quantitative assessment of the technological development’s impact on competence and skills required among future personnel in the railway sector, it is necessary to account for many variables associated with the societal development. The current work makes use of a
previously developed model for prediction of future need for competence and resources of personnel coupled to railway infrastructure. In addition, personnel involved in traffic management is mapped to establish a coherent description of the number of employees, and their distribution across professional roles, at these workplaces. Finally selected experts employed at infrastructure managers and railway contractors are interviewed to collect their views on the role of technological development for the future railway sector.

**Outputs:** The rapid technological development is expected to have a significant impact on future job profiles and skills requirements on personnel in the railway sector. On the other hand, gap in resources and skills risks becoming a bottleneck in the implementation of the technological advances. In this respect, the quantitative assessment presented as part of the current work is an important contribution that enables the identification of effective and targeted measures to build the skills that will be demanded in the future rail-borne transport system.
Creating (and sustaining) agile railway organizations: when crisis management professionalization leads de-professionalization

4.1 Introduction

Increasingly confronted with unusual situations, organizations need to develop agile capacities to deal with the unexpected. In rail systems where action is particularly planned and focused, the development of agile capabilities to deal with the unexpected often seems unnatural and challenging. To prevent crises and to cope with damaging events (Pearson & Clair, 1998), and because the management of crises needs specific skills, crisis management is now a matter for professionals (Boin et al., 2016). Dedicated crisis management teams (CMTs) composed of crisis experts are generally recommended to help organizations to manage crises with agility (King, 2002; Pearson & Mitroff, 1993; Pearson & Clair, 1998; Pearson & Sommer, 2011; Waller, et al., 2014). In Abbott’s view (1988): CMTs constitute a professional group that is responsible for crisis management. While researchers have described the characteristics of CMTs and have highlighted their effectiveness, the crisis management professionalization process remains unexplored, and should be explored, from a sociological view (Journé, 2019; Kamaté, et al, 2019). Professionalization and de-professionalization processes have recently been the subject of several management studies. Some of these studies have investigated the professionalization process of emerging professions (Huising, 2015; Kitchener, 2000; Lee Maroto, 2011; Leigh, 2014; Reed, 2018); others have improved our understanding of the de-professionalization process of well-established professions (Andrews & Waerness, 2011; Kitchener, 2000; Möller & Kuntz, 2013; Siebert et al., 2018; Thomas & Hewitt, 2011). However, despite these significant contributions, the mechanisms that lead a profession to move from a process of professionalization to a process of de-professionalization within an organization remain unexplored. This research aims to understand how this shift can take place. By focusing on how professionalization can produce a de-professionalization dynamic and how de-professionalization can stem from professionalization, it sheds the lights on the creation and the sustainability of an agile organization – a CMT - in the long term.

To do so, we consider the professionalization and de-professionalization processes as being social, relational and concurrent (Abbott, 1988; Freidson, 1970), and we follow Abbott’s work (1988), which is relevant for studying this phenomenon within an organizational context (Bureau & Suquet, 2009; Tolbert, 1990). From this theoretical point of view, a profession is “an exclusive occupational group applying somewhat abstract knowledge to particular cases” (Abbott, 1988, p.8). An occupation becomes a profession by establishing exclusive jurisdiction over a particular area and through the use of particular knowledge. This professionalization process is characterized by a competitive struggle between professional groups because professions constitute an interacting ecological “system of professions” (Abbott, 1988). According to this view, the professionalization process can lead to a de-professionalization process, which corresponds with the loss of professional jurisdiction (Abbott, 1988).

We therefore collected and analysed qualitative data from a CMT in the French railway operator (SNCF). Our findings reveal that CMT workers initially succeeded in claiming crisis management as an agile profession. However, the adaptation of the CMT also led to its de-professionalization and the loss of their agility. After a while, the team started to decline and ceded its legitimacy as a profession to the benefit of other occupational groups. Even though the organization learned about crisis management from the CMT, the CMT failed to retain crisis management as its own profession.

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注1：This report is based on a study conducted with Julien Sanchez, Oriane Sitte de Longueval, Alexandre Largier and Anouck Adrot. It has led to an article currently being revised in a scientific journal for publication.
The present document is organized in four main sections. The first draws on organizational agility definition, crisis management literature and the sociology of professions to conceptualize the emergence of CMTs as a professionalization process. The second section introduces our methodology, outlining the specificities of the case, the data generated and its analysis. The third section sets out our findings and investigates the professionalization and de-professionalization of the CMT through its story of success and failure. The fourth section considers the scientific implications of these findings and concludes by questioning the relevance of integrating crisis management as a profession and the difficulty to maintain agility within organization. The final section provides some practical outcomes by comparing the agility of two models in managing crises.

4.2 Theoretical background

4.2.1 Organizational agility to manage crisis: a matter of professionals

Organizations become increasingly aware of their likelihood to face unexpected but highly destructive events. As a result, they adopt new ways of functioning with the intention to become more “agile” on their answer to these events. Railway operations are doubly marked by the high level of complexity that railway organisations must deal with and the high level of safety/security that they have to achieve. To manage these two aspects, railway organisations are constantly seeking to avoid or anticipate unforeseen events, by establishing a procedure to be followed in normal situations and in a number of abnormal scenarios. However, despite this preparatory work, railway organisations are always faced with unforeseen or unpredictable situations to which they must react effectively. These situations constitute “organizational crisis” that must be manage as best it can. Organizational crisis can be defined as “a low-probability, high-impact event that threatens the viability of the organization and is characterized by ambiguity of cause, effect, and means of resolution as well as by a belief that decisions must be made swiftly” (Pearson & Clair, 1998, p.60). However, crises in organizations are more common nowadays and organizations acknowledge the need to fund and manage crises internally (Johansen, et al., 2012).

Without pre-established protocols, organizations must use organizational agility to deal with uncertainties in a changing and unstable environment. Agility is a complex concept, covering a lot of different elements, such as anticipation, flexibility, resilience, or organizational learning. Following Abe Harraf (2015), we defined it as a “measure of responsiveness” in crisis management. As crisis incidents can affect the survival of organizations in multiple ways, they need to acquire a complex and unique set of knowledge, core skills and standards, which leads to the emergence of crisis management as a specific profession (Boin et al., 2016). An important way in which this professionalization of crisis management is taking shape is the emergence of crisis management teams (CMTs). With previous experience of critical and sometimes traumatic events, organizations often create dedicated teams to manage crises (Pearson & Clair, 1998). In a context where crisis management has become a matter for professionals (King, 2003; Pearson & Mitroff, 1993; Pearson & Clair, 1998; Pearson & Sommer, 2011; Uitdewilligen & Waller, 2018; Waller, et al., 2014), we focus on the case of crisis management professionals who composed a crisis management team within an organization.

4.2.2 Crisis management professionalization through teams: the role of CMT

Several studies give a central role to these CMTs, which are comprised of crisis management professionals (King, 2002; Pearson & Mitroff, 1993; Pearson & Clair, 1998; Pearson & Sommer, 2011; Uitdewilligen & Waller, 2018; Waller, et al., 2014) and mainly describe the conditions of the CMTs’ effectiveness and agility. These studies highlight the need for multidisciplinary and highly experienced teams whose members combine their respective expertise to better respond to particularly uncertain, complex, and dynamic situations (King, 2002; Pearson & Clair, 1998; Waller, et al., 2014). Members of
CMTs traditionally come from within the organization. They therefore understand its strategy and have the power to take decisions internally (Pearson & Sommer, 2011). The literature highlights different ways in which CMTs can be configured. A CMT may be composed of members who are taken away from their normal duties to respond swiftly to a crisis, or of members whose full-time duties pertain to crisis management. Alternatively, a CMT may deal with local events that do not pose a significant threat to the entire organization or deal with global events that impact the entire organization (Waller et al., 2014).

In times of crisis, CMTs need to quickly share information, make sense of events to limit their impact (King, 2002) and collectively decide on a practical action plan (Pearson & Clair, 1998). In doing so, CMTs help organizations to cope with crises through faster coordination and communication (Pearson & Clair, 1998), and they help to facilitate decision making and action (Pearson & Mitroff, 1993). The fact that these teams know, master, prepare for and recall crisis situations, coupled with their ability to coordinate, and interact flexibly during the crisis, is likely to play a key role in their ability to manage crises (Waller et al., 2014). High-performing teams spend a lot of time in structuring and information sharing, and make decisions rapidly (Uitdewilligen & Waller, 2018). Some authors show that efficient CMT workers carefully identify the types of crises for which they are preparing, assess their level of preparedness and devote time to working together to better coordinate and develop common objectives for the different types of crisis situations they may face (Pearson & Sommer, 2011).

Although Pearson and Clair (1998) recommend putting the subject of CMTs on the crisis research agenda, the specificities of CMTs still raise several questions about crisis management professionals. Some authors have recently highlighted the contradiction that exists between the dominant managerial view, which requires the crisis management professionals to respect the procedures laid down by the organization, and the traditional – but undeveloped – sociological view of crisis management professionals dictating their own professional practices (Journé, 2019; Kamaté et al., 2019). Consequently, despite the many calls to professionalize crisis managers, the professionalization process remains largely unknown. Furthermore, the ephemeral nature of crises calls into question the sustainability of a profession dedicated to their management. Crisis management is an unpredictable, unstable, and ephemeral professional territory whose appropriation by a single profession seems difficult, and how to constrain the management of the unusual to professional routines remains an important challenge.

### 4.2.3 Crisis management professionalization through times: a process of struggle

Three theoretical approaches have historically structured the study of professionalization. The functionalist approach (Durkeim, 1893; Parsons, 1939; Wilenski, 1964) focuses on the intrinsic traits and attributes of a profession and considers these characteristics as initial conditions of professionalization. The interactionist approach (Becker, 1963; Bucher & Strauss, 1961; Hughes, 1960) focuses on the dynamics and stages of the professionalization process, which involves the transformation of the ordinary activity of an occupational group into the standardized, structured, hierarchical, and valued activity of a professional group. At the end of the 1960s, the debate between functionalists and interactionists gradually led the way for a new neo-Weberian approach (Abbott, 1988; Freidson, 1970), which in some cases leaned toward neo-Marxism (Johnson, 1972). Without denying its interactionist heritage, this third approach addresses professionalization from a more confrontational perspective. Proponents of this approach consider professionalization to be the result of a struggle between occupational competitors who seek to control, defend or even extend their professional territory by blocking access to their professional jurisdiction and by claiming it as legitimate in order to monopolize it. According to this approach, the de-professionalization process is the counterpart of the professionalization process.
This third approach has recently been the subject of significant interest in organizational science and has led to a series of works (Andrews & Waerness, 2011; Huising, 2015; Lee Maroto, 2011; Kitchener, 2000; Leigh, 2014; Möller & Kuntz, 2013; Reed, 2018; Siebert et al, 2018; Thomas & Hewitt, 2011). Some of these studies depict the professionalization process in newer professions, such as those of body artists (Lee Maroto, 2011), social workers (Leigh, 2014) or consultants (Reed, 2018), or in specific contexts such as bureaucratic organization (Huising, 2015). Other studies report the de-professionalization process of well-established professions such as those of nurses (Andrews & Waerness, 2011), physicians (Möller & Kuntz, 2013), medical managers (Kitchener, 2000) or medical practitioners (Siebert et al., 2018).

In line with neo-Weberian assumptions, professionalization has been examined in relation to its processes of construction and deconstruction, but the mechanisms that link professionalization with de-professionalization remain a blind spot in the field. These two processes are intrinsically linked by a fragile equilibrium that we intend to explore in this document. To achieve this, we rely on the Abbottian reading of professionalization (Abbott, 1988), which is particularly relevant to the study of professionalization and de-professionalization in relation to the ecological system of professions and within organizations (Bureau & Suquet, 2009; Tolbert, 1990). Whereas Abbott (1988, p.66) points to the “fuzzy reality” of jurisdictional relations in the workplace, we consider that his work is particularly relevant for studying this reality because it puts the work activity at the heart of professionalization.

According to Abbott (1988), during its process of professionalization, an occupational group claims to address a problem and tries to give strong legitimacy to its own interpretation of the problem. By doing so, professionals claim their right of jurisdiction, defined as the link between a profession and its activity. This claim involves the diagnosis of a problem, its treatment and an inference between the diagnosis and the treatment. These three actions underpin the professional practices that are formalized in an academic knowledge system. They are used to legitimize the jurisdiction, to find new professional practices and to maintain domination through education.

Professions and professionals create and protect their jurisdiction thanks to the work described above. However, their legitimacy to retain this jurisdiction is constantly questioned by audiences and competed for by other occupations (Abbott, 1988). Audiences assess and influence the attribution of jurisdictions; they are outside of the system of professions but are interested in the service delivered by professionals. Competing occupations try to extend their own professional boundaries; they reside in the system of professions but are interested in taking over all or part of the jurisdiction held by the professionals. Professionalization is stabilized when inter-professional competition for the jurisdiction is counterbalanced with the position of audiences. However, professionalization remains an undefined and uncertain process. It is driven by the struggle between professional groups, which battle each other to control jurisdictions. When they lose these political battles, professionals run the risk of losing their legitimacy and engaging in a de-professionalizing process (Abbott, 1988). Within organizations, the inter-professional division of labour is replaced by an intra-organizational one. In the workplace context, professions are extremely vulnerable to organizational structuration and perturbations (Abbott, 1988).

Based on the work of Abbott (1988), this research explores the professionalization and de-professionalization process of a CMT to better understand the mechanisms which articulate the professionalization to de-professionalization dynamics within an “agile” organization.
4.3 Methodology
This research draws on ethnographic data and a processual analysis of a unique case study. Our methodology is described in three sections covering the research context, the data collection process and the data analysis.

4.3.1 Research context
Our research took place in the French SNCF railway company, which manages complex rail flow management. In 2009, SNCF created a CMT to manage crisis situations to provide a safer and more efficient system of human flow management especially around big stations. In the area studied, the latest survey estimated that 2.5 million people were using the network each day to travel between their home and workplace. At the time of the study, the CMT was composed of 5 rotating teams, each with 18 employees (90 employees in total), which could be mobilized every day of the year and at all times of the day whenever a crisis event took place. They were composed of security and sales employees working together. When a crisis arose, the CMT would go to the site of the incident (a train or a station), where they would guide travellers and, when possible, provide them with water, food and taxis. They reassured them by their presence and protected the organization and its employees from a potential overflow of travellers. The rest of the time, the team undertook preventive activities. This study focuses on the eight-year story of the CMT, from its creation in 2009 until its quasi-extinction in 2017.

4.3.2 Data collection
We took an ethnographic approach to report the language, actions, interactions and objects of the team (Ybema et al., 2009) using three data collection techniques: observations, interviews and documents.

We began with the observations, spending 57 days with the team’s managers at the CMT’s headquarters. This enabled us to participate in the daily life of the unit and to better understand the internal and historical dynamics of the CMT. We also conducted 11 observations with the team in a train station, spending an average of eight hours per session. We used an observation table and focused on interactions within the CMT and between the CMT and its environment. This enabled us to observe situational and interactional dimensions of the daily activities and functioning of the CMT. It also gave us the opportunity to have many exchanges with CMT workers.

To access the CMT workers’ perceptions and the CMT’s stories, we conducted 15 interviews with CMT employees (7) and their managers (8), some of whom had been in the team since its creation, while others had just arrived, and two managers had recently left. The interview guide covered three main areas. The first focused on the professional trajectory of the interviewees, including their arrival in the CMT. The second investigated the CMT’s role, functioning, practices and culture. The third focused on the daily activities of the CMT, the daily interactions within the team and between the team and its environment, their evolution over time and their future. The interviews lasted between 33 and 160 minutes, 75 minutes on average. Each interview was recorded on a digital voice recorder and then fully transcribed to analyse the data.

We also collected documents to better understand the story of the CMT. We used job descriptions, procedures, security rules, organizational charts, and press articles, and we obtained activity reports of different work situations, annual operating reports and meeting reports.

4.3.3 Data analysis
Our analysis is based on the articulation of two different strategies for theorizing from processual data and three levels of coding.
First, we used a narrative strategy (Langley, 1999) to (re)create the detailed history of the CMT from the raw data. Taking an ethnographic approach, we focused on contextual details and important events in the CMT’s stories to reconstruct its temporal dynamic. To do so, we analysed the CMT’s stories as told by its various members from when they arrived to when they left the team. We also used various documents to confirm or qualify the stories. Using each testimony as a resource, we chronologically reconstructed the story of the CMT through a first level of open coding. At first glance, it appeared that the CMT had experienced two different periods with contrasting characteristics.

Next, we used temporal strategy bracketing (Langley, 1999) to get a more structured view of the periods and mechanisms of this dynamic. In the sociology of professions, we found a relevant theoretical way of structuring the description of events, and we decomposed the story of the CMT through a second and third level of coding adapted from the theoretical perspective of Abbott (1988). These codes were used to identify, describe and delineate the different mechanisms and periods of the professionalization and de-professionalization process studied.

After analysing the data separately, the researchers met regularly to discuss and debate the findings and their analysis until they reached a consensus. These stimulating meetings helped to deepen our understanding and our analysis of the phenomena under study. The different levels of embeddedness of the researchers, half of whom were insiders (having worked in this CMT from the beginning of the study and for several years as researchers for the organization’s Human Resources Department) and half of whom were outsiders (who worked in another field in the same organization and in other similar fields) allowed us to maintain an insider–outsider perspective during the analysis.

The most telling data were selected and translated to illustrate the themes, concepts and dimensions presented in the following section.

### 4.4 Results: the story of the success and failure of a crisis management team

The CMT was created following the occurrence of a major crisis in a French railway station. On 13 January 2009, a traffic interruption resulted in a riot within a large station. This incident caused serious material damage and the sales and security teams in the station had to deal with some very concerned clients. The critical nature of the situation led SNCF to decide – for the first time in its history – to close the station and to evacuate the travellers. To achieve this, the station staff improvised logistics to calm passengers and relieve the congestion. Feedback from this incident highlighted the spontaneous enactment of innovative practices which had a positive effect on the outcome of the crisis.

As a result, the top management decided to create a brand new team dedicated to the management of future crises, which they called the “Rapid Assistance Team” (“Equipe d’action rapide” in French) in reference to its agility. The CMT was officially created on 24 October 2009.

“When things went wrong in the station, a lot of people were waiting, and we were quickly overwhelmed. This was not enough. In those very specific situations, we are supposed to look after customers by welcoming them, providing information, and channelling them, at a time when there are so many of them and they are not in a good mood. So, we created a flying team, able to intervene anywhere, at any time, a bit like the ‘ghostbusters.’ We organized this team, we gave it a boss as a coordinating agent. We realized that it had both positive and negative effects, and this is where the surprises began.” (Extract from the minutes of a meeting – intervention by SNCF senior executive about its crisis management team)

The founders of the CMT decided to staff it equally with former sales and security workers and to recruit a former director of both the sales and security departments as the director of the CMT. At this stage, the CMT was officially responsible for welcoming passengers in distress and/or supporting the
train stations and their local occupational groups when they had to deal with critical events. Even though the crisis jurisdiction of the CMT was set out at its creation, the team had to overcome several serious difficulties to establish itself and crisis management in the organization’s portfolio of professions.

Our core findings reveal three key episodes from the creation of the CMT to its decline. In the first episode, we describe the efforts made by the CMT to claim its jurisdiction as crisis professionals over the rest of the organization and to build the team up. The second episode corresponds to the peak of the CMT’s professionalization efforts to support crisis professionalization from the inside to the outside. This phase laid the foundations for the third episode, which is the decline of the CMT and its de-professionalization to the benefit of the professionalization of other occupational groups.

4.4.1 Conquering the outside and creating the inside: claiming crisis management as a profession

During this first period (2009–2012), the CMT workers made a great deal of effort to claim their responsibility for this jurisdiction, particularly to capture an audience, to be accepted by competing occupations, to develop crisis management competencies from scratch and to build their own professional identity despite the composite nature of the team.

- Capturing the audience’s attention and the trust of competing groups

To assume this jurisdiction for crisis management, the CMT had to develop its own body of professional knowledge and to organize its own functioning model. However, to learn how to manage crises, the CMT first had to have access to them. To gain this access, the team had to convince the audience to inform them of crisis situations and it had to convince competing groups to accept their presence in crisis situations. At that time, most of the organizational members and groups expressed some scepticism about the CMT and sometimes even mocked it. Even one of the founders of the CMT had doubts about the long-term existence of the team as a distinct entity.

In this context, the CMT workers made great efforts to capture their audience and to ensure that everyone was aware of the team’s existence and its activities. They informed as many people as possible about their crisis management jurisdiction and explained the added value of the CMT to the overall functioning of the organization. Their aim was to ensure that station workers reported crises to the decision makers and that the decision makers mobilized the CMT to manage these crises. At the operational level, the CMT workers presented their competencies to other occupational groups in the stations. At the managerial level, the CMT leader advised the organization’s management and representative bodies of the CMT’s scope by actively participating in internal meetings and communications:

“[The first leader of the CMT] was selling our service, ferociously; she also didn’t hesitate to make us known.” (Exchange between a CMT worker and the observer during an observation, O9)

This lobbying of the audience enabled the CMT to take control of how it was triggered into action whenever there was a new crisis in the stations.

But to pursue its activities and manage crises, the CMT also had to battle against resistance from competing occupations. In the stations, security and sales workers thought that joining the CMT could potentially jeopardize their professional career. This made it difficult to recruit qualified staff for the CMT. Furthermore, the arrival of the team in the stations was perceived as a threat by the local occupational groups because they were worried it would lead to them losing their jobs. The CMT workers were perceived as intruders by local staff, and they were uninvited and unwelcome in the
stations. To gain their trust, the CMT refused to be used as a substitute for local occupations when there were no potential crisis events taking place. Thus, local occupational groups felt less threatened by a reduction of their professional territory. The reaffirmation by the CMT of the inviolability of each other’s borders and each other’s territorial integrity contributed to its acceptance:

“This is why we do not replace [local occupational groups]. When a request does not fit our mission, we refuse it. We do not share our territory, and no one encroaches on others’ turf. So we do not steal others’ jobs, and the others should not steal our job either.” (Nicolas, CMT worker from 2009 to 2017, W1).

In this way, the CMT workers convinced competing groups to delegate crisis management to them and to share local information with them at times of crisis. Having been rejected for a time by the station staff, the CMT eventually managed to position itself as a support rather than as a substitute for them. The CMT quickly became an ally and a career springboard, and there was a waiting list to join the team. The team’s success in managing crisis events eradicated all the initial doubts, and the scepticism of competing groups was gradually replaced with recognition.

- **The development of crisis management competencies**

  The CMT’s access to crisis management enabled the emergence of basic features of its professionalization and specific professional practices for assessing and dealing with crises. Based on each person’s previous skills, and according to the different crisis situations they had to manage collectively, they built new professional knowledge, new professional practices and a new professional ethic:

  “With respect to behaviours and the words they use, they are the best and I mean it. No rude words, full respect for ethics, unlike other services. We are used to acting in complicated settings, so dealing with angry clients is our daily work: our employees are thus fully prepared for that.” (Julien, CMT Instructor from 2009 to 2017, W4)

  To maintain their skills and ensure successful operations, CMT workers undertook exercises, improved their knowledge of the field by visiting railway stations and held debriefs with their peer group. The CMT’s efficiency improved to the point that its members were perceived as an elite, more qualified than other professional groups to deal with crisis situations.

- **The construction of the professional identity of a crisis manager**

  To build its own professional identity despite its composite nature, the CMT had to recruit members who would fully assume the identity of the CMT and eventually abandon their identity as members of the sales or security service they had previously been part of. To do this, the CMT developed a professional identity which diverged from the rest of the organization and was strongly embedded in crisis management. While critical settings represented a threat to the whole organization, they were a source of excitement and satisfaction for the CMT workers, as one of them explained:

  “It is quite paradoxical. When the situation is bad, it means that the whole company is not going well. But at that time, CMT workers are happy because they can show off their skills.” (Lucas, Staff Manager of the CMT from 2009 to 2017, M4)

  The strengthening of their identity was supported by identity markers. The team developed its own motto and line of uniforms designed specifically to unite its members symbolically. Their mantra was
“1 security worker + 1 sales worker = 1 CMT worker” and the purple color of their uniform erased their former sales and security identities, in the name of professional unity.

After this intensive period of winning others over, in 2010, the CMT’s efforts to professionalize were recognized with an internal award. Crisis management was then universally recognized as the jurisdiction of the CMT and the success of the team was such that it attracted interest from all quarters.

4.4.2 Normalizing the inside and sharing with the outside: the diffusion of professionalization

During this second period (2012–2014), CMT workers were called upon to act in many situations and to share their experience on different occasions. To meet this demand, the CMT had to standardize its functioning, to concentrate its jurisdiction around crisis management and to diffuse its crisis management knowledge.

- The standardization of the CMT’s functioning

After a period of intensive demonstration and creative building, the CMT and its activity had grown considerably. Many people had been informed of its existence and convinced of its professional legitimacy. The CMT pioneers had been joined by many new recruits and the size of the team had multiplied nine-fold. The team’s crisis management skills had expanded through the different crises. It was now often very busy and at times a little overwhelmed. The CMT workers were known throughout the organization and were recognized as crisis professionals; they needed to normalize their functioning to make the profession sustainable within SNCF. A new era began for the CMT with the replacement of its leader. As she herself explained:

“What we were asked to do at that time was to stabilize the work of the CMT. We had to find a way to maintain this pioneering spirit, this laboratory spirit, to test new ways of doing things in the long term. This is hard. The most difficult [long silence]. At the beginning, there was no shortage of ideas, I know that even when I left, I had lots of ideas, but I had to pass the torch because, physically, it was tiring. Exciting but, physically, a bit hard.” (Julie, First CMT Top Manager from 2009 to 2012, M7)

While the CMT’s first top manager was highly involved in promoting the CMT to the outside, the second was more focused on the internal working of the team. Under his leadership, the team regulated its internal operating methods so that they could be more pragmatic, and it developed specific training to formalize its professional practices. Finally, the CMT established reporting mechanisms to quantify and report on its activity to the rest of the organization.

- Concentration of the CMT’s jurisdiction around crisis management

In the face of huge demand for their services (up to forty-two requests a month and an average of six or seven a week), the CMT became increasingly swamped and had to be more specific about its mission statement. This was an opportunity to concentrate the CMT’s jurisdiction around crisis management. The team then reflected on how to prioritize its missions. Four categories were defined and ranked according to their increasing importance in terms of crisis management. The first category covered so-called “visibility missions”. This involved action to combat fraud and antisocial behavior in the stations that were most at risk, but in the absence of crisis events. The second category included the prevention of potential crises by physically going to cities hosting risky events such as cultural or sporting events. Because these two types of missions were considered as “scut” work by the CMT workers, they had the lowest value and were still marginal to the daily operations at that stage. In parallel, the CMT sought to focus its efforts on the third and fourth types of activities, which were perceived as having
the greatest value. These involved managing so-called “disturbance events” and “crisis events”. They were the core activity and the noble part of the crisis management work. From the CMT workers’ point of view, activities with the lowest impact on crises allowed them to relax or make changes to their work environment while they were waiting for the next crisis.

However, activities with the highest impact on crises enabled them to demonstrate and improve their crisis management skills. Once formalized with its audience, this refocusing of the CMT’s activity enabled the team to minimize the time spent managing pre-crisis situations and to maximize the time spent managing post-crisis situations. But this segmentation also corresponded to the organizational logic of the SNCF French railway company, which, like many organizations that manage high-risk activities, is committed to defining everyone’s role in every possible situation. However, as the following extract explains, it was difficult for the CMT to identify developing crises and to segment their complex and transverse management. This division of the crisis management jurisdiction resulted in the CMT’s attention being focused on its borders with neighbouring occupations rather than on crisis management:

“The mainspring of the CMT is the fear of a crowd getting out of control. The CMT manages the big crises but there are a lot of small crises that are likely to degenerate and can be managed in advance. [Other occupational groups] are there more to manage the daily incidents that are not visible at the system level and the CMT intervenes when the crisis is visible for everybody. [...] And then, as always at SNCF, it starts to get bureaucratic. Right. Classic. SNCF is a company which, because it deals with the unexpected, tries to anticipate everything. We believe that if we write everything down in advance, people will know what to do when it happens. So we describe 150 possible situations like this, and when it happens, we’ll be able to take sheet 122. But the day it happens, by the time we find sheet 122, the thing is already screwing everything up, and it’s not 122 but 154 that is needed, and so on. The sad thing is that [the occupational groups] are put into so many boxes that they’re talked about the box boundaries rather than the service to be provided. When you create a repository, you immediately show people where their job begins and ends.” (Penelope, CMT Head Manager from 2011 to 2014, M8)

After the introduction of this concentration of activity, the CMT was subsequently less often called upon; use its services were progressively reserved for the most important disturbance and crisis events, and other occupational groups had to take over part of its scut work.

- **The diffusion of the crisis management knowledge**

To fulfill the expectations of its audience and other occupational groups, the team had to share its competencies. While the directors and sponsors had initially agreed that the CMT workers would remain in the service for only three years in order to promote the diffusion of crisis management skills to the rest of the organization, they rarely moved out of the team and tended to settle there. As a result, the CMT workers strove to pass on their crisis management knowledge to the rest of the organization through conferences, feedback, internships and statements of good practice. By doing so, the CMT – as crisis experts – helped to develop a stronger crisis management culture and diffused a better understanding of crisis management in the organization and within stations.

Through the CMT’s experience, the organization and its occupations improved their own competencies to deal with the crises they faced. Subsequently, a new occupational group – the Mobile Railway Crew (MRC) (EML in French) – was created among commercial staff to manage daily crisis situations in stations. Sometime later, an existing occupational group – the Information Volunteers (IVs) (VI in French) – was developed and professionalized in the same way. The IVs were made up of novice
employees who interrupted their daily work to help customers during disturbed situations. Ultimately, the crisis management professional portfolio in the organization was considerably enriched because of the CMT’s experience. As Raphaël said:

“The stations have become more professional in terms of their staff... Whether it’s the MRC, the IVs: they have copied our techniques... We have professionalized them.” (Raphaël, CMT Staff Manager from 2009 to 2017, M2)

These new occupational groups gradually replaced the CMT in managing minor crises, limiting their aggravation while waiting for the intervention of the CMT, and assisting the CMT to manage major crises.

4.4.3 Losing the outside and undermining the inside: the rise of inner contradictions and de-professionalization

During this third period (2014–2019), the CMT lost its professional jurisdiction and realized that it had itself laid the foundations for this. Once the CMT had established the foundations of its professionalization, its members realized the ambivalence of these foundations. The CMT faced a reduction in its crisis management jurisdiction, the decline of its crisis management skills and the disaggregation of its crisis management professional identity.

- The reduction of the crisis management jurisdiction

Requests for the services of the CMT became quite rare for several reasons. First, its emphasis on major crises limited the frequency of CMT requests. Other professional groups increasingly assumed the scut activities delegated to them by the CMT. Because they were often already on site, the MRC and IVs gained ground and were now the first to be mobilized to handle minor crisis situations, which were also the most frequent. The diffusion of the CMT’s knowledge and skills allowed them to handle difficult upstream situations, which meant that major crises could be avoided more easily and become rarer. At the same time, efforts to capture the audience and to convince competing groups decreased as a result of the CMT’s focus on its own standardization. Actors who were entitled to trigger the CMT became less convinced of its effectiveness, or even less aware of its existence. They increasingly mobilized other occupational groups at the expense of the CMT. In some cases, even when a major crisis was signalled, the CMT was simply forgotten about by those who might trigger it into action. In most cases, when the CMT was actually called upon to manage major crises, it was often as a last resort and therefore too late; the crisis had passed, after being handled by the local teams. This is precisely what we observe in the following situation:

“We had been triggered by the command center. But when we arrived, they explained to us that the situation had been solved. The station had been overcrowded with people and the local staff had had trouble dealing with the situation. When we arrived at the scene of the incident, the local staff seemed quite surprised to see us and told us that the ‘battle was over.’ Seemingly, they had been waiting for the CMT for a long time. The CMT were quite disappointed and embarrassed by the situation.” (Extract from the observation diary, O2)

As they were aware that the CMT was losing its professional territory, the CMT workers refused to give us actual figures about their activity and tried to reverse the situation. But they were now constrained by the rigidity of the standards that they themselves had put in place to regulate the functioning of the CMT, and which had since been institutionalized. The CMT had now lost control of its own processes. To deal with this lack of autonomy, the CMT workers tried to regain some ground. They bent organizational rules and chose not to obey some orders, but this was not enough to counteract the
dynamics that were underway. In stations, their daily activities were increasingly mocked, and they were described as useless. The top management was beginning to question the role of these professionals whose services were rarely requested and were often sought too late. Maintaining a dedicated team for crisis management became a cost that had to be justified. Rather than disappearing completely, the CMT gradually agreed to become a “repair squad” for the daily organizational life. The team increasingly undertook activities that did not involve crisis management. Most of their time was eventually taken up with missions they had initially limited or refused. The CMT was now mainly engaged in non-crisis management missions, like being visible in stations, and replacing other occupational groups in non-crisis situations.

- The decline of the crisis management skills

As a result of the decreasing demand for managing critical situations, the CMT also had fewer opportunities to train and learn, which impeded the development of their expertise, an essential ingredient of their contribution to crisis management. As a result, the CMT workers started to get bored and to lose their expertise. Their core professional skills gradually disappeared along with the training that, until then, had been specific to the development and preservation of their expertise. A gap gradually developed between the experienced workers and new recruits, who had few opportunities to manage crises, between the declared and the real crisis management competencies of the CMT workers, and between the CMT and its competing occupations, which were now sufficiently skilled and trained to better manage some situations than the CMT. One CMT worker told us the following disappointing story:

“Today we are afraid of the MRCs, because they can do things now... For example, when there was the double murder in [train departure town] station, MRCs were sent to handle the customers in [train arrival town] station. They weren’t even MRCs from [train arrival station], they were from [other station]. We saw them arrive; we were very surprised. And we talked with them, they said, ‘We’re a little bit stunned.’ But they were very dynamic, they were faster than us. And I looked at my colleagues, and I said: ‘I don’t know if you realize what’s happening: they’re faster than us, but they don’t have the information, they’re not trained, they don’t have the equipment...’ But they’re better... So I think that now we have to show that there are things that they won’t be able to do. We need to actually... It’s a stupid thing to say... But it’s almost a matter of survival, but... we have to show that we can do extra stuff [even if it’s not crisis management].” (Roméo, CMT Staff Manager from 2009 to 2017, M4)

By losing its crisis management skills, the CMT lost its legitimate existence. The CMT workers progressively lost control of their professional jurisdiction and the effectiveness of their action was thwarted.

- The disaggregation of the professional identity of the crisis manager

In this context, the CMT started to look for things to do in stations, to “find work”, and to relieve the tedium. To do so, they renewed their own mission and returned to their former occupations. The workers from the service occupation focused on advising and accompanying customers in their purchases and travel, and the workers from the security occupation turned to enforcing regulations and anti-fraud activities. Ultimately, the efforts of the CMT to develop a unique and hybrid identity were called into question by their lack of crisis management activities. The sense of belonging faded among the members of the team, who had split into two sub-groups which tried to coexist more than they cooperated.
Whereas the members of the CMT seemed particularly proud of their identity in the years that followed its creation, they ended up doubting their own legitimacy for managing the crisis jurisdiction. The longer-standing workers of the CMT became frustrated and demotivated and the newcomers were far from adopting the crisis manager identity that had been constructed by their predecessors. This identity and its symbols came to be challenged. The CMT workers gradually returned to their former professional identities and did not to wear their purple uniform. In the end, they became the main critics of the CMT’s mantra, denied the existence of a common identity and saw the CMT as an awkward aggregation of distinct professions. They had very strong statements about the CMT project:

“Our mantra is that 1 security employee + 1 sales employee = 1 CMT employee. I would add = a stupid idea. Our work is supposed to be the same, but our professions fundamentally differ.”
(Exchange between a CMT worker and the observer during an observation, O2)

Whereas they had hitherto built their strength on the complementarity of their respective previous professions, cohabitation in the team became a constraint for all. If crisis management united them, its absence divided them. While the image of the crisis management professional persisted outside the CMT, it was no longer relevant inside the team. In the following exchange, it became clear to us that, as researchers, we had been deceived by this illusion at the beginning of the study.

“As we wandered aimlessly through the station, a CMT worker asked me to explain again the reasons for our presence. Like when we arrived, I told him that we wanted to conduct research on crisis management professionals, and that we chose to study the CMT because of the heroic image that had been painted of it. He smiled as others had already smiled when hearing this speech on our arrival. He said: ‘Oh, it’s funny that they still think that!’ I replied that, as observers, we were also surprised by the lack of crisis management activity in the CMT. He answered me with a complicit look ‘Well, there you go, you’re starting to understand’.”
(Exchange between a CMT worker and the observer during an observation, O6)

As they saw that the situation was deteriorating, some of the workers asked for a transfer. As the CMT was mainly being used to compensate for the under-staffed security teams, the CMT board became absorbed by the security department and lost its independence from other occupational groups. At the end of our study, the CMT workers were concerned about a plan to reduce the number of staff by 90 percent. Today, the story of the CMT’s success and failure is considered to be history.

4.5 Conclusions and recommendations
This survey allowed us to explore in depth the successful implementation and the frustrated sustainability of a dedicated professionals’ team to manage crises in a railway company. From our conclusions, we draw several practical outcomes. We propose here a comparison of the agility for managing crises between the two following models:

• THE PROFESSIONAL GROUP MODEL: developed from the CMT survey.
• THE EXPERT NETWORK MODEL: developed from other experiments at SNCF.

A discussion group was set-up within the company studied to discuss the agility of these two models in the face of crises. This group was made up of internal experts specialising in organisational and human factors in the face of risk. During the discussions, five aspects appeared to us to be decisive in the agility to manage crises. It is therefore on these five aspects that the benefits and limitations of these two models will be systematically compared.

• Matching workload/worker availability
• Localization
• Skills
• Link with the rest of the organization
• Organization and perennial

The following Table 1 concludes this study by detailing the comparison of the agility of the professional group model and the expert network model for managing crises.
### Table 1. Comparison of the agility of the professional group model and the expert network model for managing crises

<table>
<thead>
<tr>
<th>ISSUES/features</th>
<th>Characteristics of the PROFESSIONAL GROUP MODEL</th>
<th>Characteristics of the EXPERT NETWORK MODEL</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Main benefits (+) and limitations (-) identified</td>
<td>Main benefits (+) and limitations (-) expected</td>
</tr>
<tr>
<td></td>
<td>Illustrative examples from the CMT survey</td>
<td></td>
</tr>
<tr>
<td>MATCHING WORKLOAD/WORKER AVAILABILITY</td>
<td>The crisis management activity is fully managed by professionals who are entirely dedicated to it.</td>
<td>Under normal circumstances, the experts go about their respective duties. When a crisis occurs in their station, they assume their role as crisis management experts to guide the members of their professional group. Several experts can thus cooperate (e.g. traffic expert, security expert, customer assistance expert).</td>
</tr>
<tr>
<td></td>
<td>(+) Benefit of having a team of professionals dedicated to crisis management to handle the extra workload When stations and their teams are overwhelmed by events, they can call on the CMT to compensate for the lack of available workforce.</td>
<td>(+) Allows the availability of the experts in charge of the crisis activity to be adjusted on a case-by-case basis. Experts can be detached from their day-to-day work to focus on the crisis management activity. For example, in the event of a major incident, the company’s psychologists are called upon to interrupt their daily work and to go to the site to deal with the psychological damage caused by it.</td>
</tr>
<tr>
<td></td>
<td>(-) Difficulty in adjusting between the fluctuating workload of the crisis management activity and the more difficult availability of crisis management professionals The CMT workers have first too much and then not enough activity. As a result, the size of the team is first adjusted upwards and then downwards with significant professional and psychological costs.</td>
<td>(-) Need to have experts available in each station with representatives from each profession involved in the management of the potential crisis Experts can be only deployed in the event of a major crisis, often lasting several days. In less important or more specific situations, the system is not activated. The normal mode of operation continues.</td>
</tr>
<tr>
<td>LOCALIZATION</td>
<td>Professionals are waiting in their premises where they are pre-positioned in stations deemed “at risk”. They go to the site of the crisis when they are triggered</td>
<td>The experts are pre-positioned in stations or on perimeters where they carry out their normal activities. When a crisis occurs in their station or perimeter, it is the local experts who are called upon to manage it.</td>
</tr>
</tbody>
</table>
**(+)** The professionals are available in a headquarters and can intervene at any time in the surrounding stations and go there by train or truck. When stations and their teams request the CMT, it goes to the site as soon as possible.

**(-)** Difficulty of access to the crisis site in time, from the professionals' initial position, especially when transport is disrupted. When they are triggered, CMT agents often arrive too late at the place of the crisis, and it is the premises that had to manage it while waiting for them.

**(+)** Allows the creation of a network of experts predisposing potential crisis managers throughout the railway territory. Experts can participate regularly in an on-call system that can be reached at any time. For example, the company's train drivers have a telephone number on which they can reach a crisis expert driver for assistance at any time.

**(-)** As the frequency and importance of the crises to be managed vary from one station to another, some experts can be located at a distance from the stations concerned. The experts available are profession-based specialists but are not always well versed in the local specificities of the crisis to be addressed.

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**SKILLS**

Professionals build their own crisis management skills.

**(+)** The creation of a professional group dedicated to forging an ad hoc stock of crisis management skills and professionalizing crisis management at the organization level. The competences developed and shared by the CMT have allowed to considerably improve crisis management in the company.

**(-)** Dilemma between retaining crisis management skills at the professional level to the detriment of the resilience of the organisation and disseminating skills with the rest of the organisation to the detriment of the added value of the profession. By sharing their competences with the rest of the organisation, the CMT officers certainly contributed to forge a better crisis management at the global level, but they also trained those who eventually took their place.

**(+)** This encourages the sharing of skills at the global level, while guaranteeing the status of expert at the local level. Experts have a vested interest in sharing their knowledge across the expert network (to become and remain part of it). The network has a vested interest in disseminating this knowledge throughout the organisation (to legitimise itself and be solicited). For example, innovation experts in the company are part of a network that regularly evaluates their contribution.

**(-)** The level of skills in crisis management being partly dependent on experience of crises, experts being in less concerned stations may have a lack of skills. Experts do not all have the same level of qualification and experience depending on the problems for which they are called upon. For example, the company's human and organizational factors experts sometimes lack the skills to deal with requests.

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**LINK WITH THE REST OF THE ORGANISATION**

The professionals partly disconnected themselves from the rest of the organisation to forge their own identity and organisation adapted to crisis management.

**(+)** The independence of CMT has enabled it to build a new and interstitial identity and organization in the company. The CMT has built a way of understanding and managing crises that has never been seen before in companies and has positioned itself as an intermediary

**(-)** Difficulties in keeping in touch with the profession's triggers and interlocutors and difficulty in managing crisis situations without always knowing the usual operating methods and actors in the station affected by the crisis.

**(+)** This dual anchoring enables them to rely on a double link. A link with the location of the crisis: knowledge of the geography, organisation, and sociology of the station/perimeter and that of its workers (colleagues). A link with the network of experts: knowledge of crisis management

**(-)** Experts may be caught in conflicting injunctions related to their double anchorage and it can be time-consuming. They may also be limited in their capacity to manage crises because of the local social dynamics in which they are caught. It is conceivable that an expert with little
| Organization & Perennial | Professionals are organized like a classic professional branch with their own executives, HR management, managers, recruitment...The future of the professionals is intimately linked to that of crisis management. The animation of the network (steering, training, interactions...) is ensured by dedicated managers and processes. Experts may remain so for a longer or shorter period depending on their aspirations and results. Their professional destiny is primarily linked to their normal activity in their respective professions. (**) Organisation of WCL follows the traditional professional organisational mechanisms in the organisation (recruitment, training, allocation of resources, supervision). Once created, the CMT was provided with its own premises, managers, operators, resources, and rules. (**) The status of expert can be valued in the expert's profession and gives rise to a specific and additional remuneration. But it is not the sine qua non condition of the activity. Experts remain valued by their normal activity, even when there is no crisis to manage. For example, railway driving experts remain drivers in parallel with their expert activity. (-) Better crisis management at the organizational level condemns these professionals to boredom or disappearance. The CMT struggles to keep busy and to retrain when crises become rare. (-) The valuation of the expertise activity within the company may be perceived as low in comparison with the investment of experts and the skills they develop in crisis management. Experts may be dissatisfied with the low rewards associated with their important contribution to the network. | methods and contacts at local level (e.g. taxi companies, emergency services, restaurants, hotels, etc.) but also at global level (operating methods and contacts for system-wide crisis management). Experts are boundary spanners between the operational unit in crisis, the network of expertise and the organisation. For example, the 'organizational and human factors' experts work in their operational unit but maintain regular relations with the network and privileged relations with the organisation. Legitimacy with his colleagues at the local level will also lack legitimacy with them in a crisis. Being a boundary spanner can also create contradictory injunctions and conflicts of interest. For example, the 'organizational and human factors' experts may be both tempted and discouraged from revealing security vulnerabilities identified in their business unit to their expert network. | between different actors who have hitherto kept at a distance. The CMT struggles to legitimize itself with the stations. It succeeds in doing so at the cost of important lobbying efforts. But at the first slackening of these efforts, they are forgotten. |
5 Future skills and qualifications in the railway sector

Shift2Rail is a European initiative set out to accelerate the integration and uptake of new and advanced technologies and innovations in the railway market. The joint effort on technology development performed by Shift2Rail is set to improve the competitiveness of European rail industry and support the fulfillment of overall targets such as doubling of rail capacity and halving of life-cycle costs. These challenges at transport system level are addressed by technology development and innovation in any of its subsystems (e.g. infrastructure, vehicle design, signalling system, etc.). To support efficient uptake by the railway market and to bridge the gap in scales between proposed innovations and their associated effect on the transport system, Shift2rail includes so-called cross-cutting activities (CCA). As part of the CCA, the current work highlights changes in skills needs and job profiles of personnel in the railway industry brought by technological development.

The current report is the final deliverable from IMPACT-2 WP8 “Human capital”. It builds on, and complements, previous deliverables D8.1 and D8.3, as well as work performed as part of open-/tender call project members for which WP8 has acted point of contact (Metzger, 2018; Metzger 2019). With respect to the latter, the so-called Human capital report series performed by TNO and Newrail deserves special mentioning (Dhondt et al., 2018a; Dhondt et al., 2018b; Dhondt et al., 2019a; Dhondt et al., 2019b; Dhondt et al., 2019c). These reports were prepared in active collaboration with IMPACT-2 WP8 and the content closely relates to the objective of the current work.

The content of the current Chapter relates to WP8 task 8.2 “Skills and qualifications”. The objectives of the study are presented below. In Section 5.2 challenges in the railway sector associated with human capital is briefly described. The work performed as part of the TNO Human capital report series is reviewed on the basis of the scope of the current deliverable. Section 5.4 outlines S2R technological demonstrators (TDs) together with a discussion on their potential impact on future skills and qualifications. The impact of technological development on future competence and resource needs is investigated in a case study that focuses on the Swedish railway market. Numerical predictions and responses from expert interviews are presented in Section 5.5 and Section 5.7, respectively. Section 5.8 presents results from a workshop held to assess the transferability of the results obtained for the Swedish railway sector. Conclusions are found in Section 5.9.

5.1 Objectives

The current work complements previous studies performed and reported as part of the activities in IMPACT-2 WP8 (Metzger, 2018; Metzger 2019) as well as by the research tender TNO (the Human capital report series). More specifically, the contribution by this study relates to requests in WP8 task 8.2 “Skills and qualifications” (Grant Agreement number 777513). At the same time, it is an attempt to accommodate comments received during the reviewing of previous deliverables. Against this background the following two main objectives have been formulated:

1. To make a quantitative investigation of the impact of technological development on the future composition of competence and staffing need in the railway sector
2. To examine the connection between the development carried out in S2R represented by the TDs and their impact on future skills and job profiles

5.2 Method

Detailed data on employment levels within the European railway sector is currently not available. The great benefit of having access to such dataset is described in D8.1 (Metzger, 2018). By combining data
from a mapping of available resources and professional roles in the railway sector with a list of technologies that are expected to be introduced in the near future, both the potential impact on future need for resources and skills as well as recommendations on measures to bridge the gap between current and future job profiles can be assessed (Metzger, 2018).

The two objectives in Section 5.1 have been assessed using different research methods:

1. The Swedish railway sector is used in a case study. Due to a recently completed national research project, data that correspond to the requirements outlined above are available for the part of the Swedish railway sector related to the infrastructure. Further, in the same project, a model for prediction of future needs for personnel with railway specific competences was developed. This model is applied in the current work to present a prognosis for the future development on the labor market. These results do not account for the impact of specific technology innovations. Instead, this is addressed by interviews held with selected experts at railway contractors and at the infrastructure manager. Finally, the transferability of the results to other European countries are discussed in a workshop.

2. In D8.1, a mapping between S2R TDs and their impact on future job profiles is introduced. This is later further developed in D8.3 (Metzger, 2018; Metzger, 2019). In parallel, Dhondt together with colleagues at TNO has investigated gaps in skills requirements in relation to the S2R TDs (Dhondt et al., 2019a). In this regard, the contribution of the current deliverable is to combine these two resources while at the same time strengthen the link to specific technical solutions proposed by S2R.

5.3 Background

The railway sector is subjected to great expectations in the development of sustainable mobility solutions for the future of Europe. The European commission outlines its ambitions in the Sustainable and smart mobility strategy (European commission, 2020). For example, until 2030, high-speed rail traffic in Europe should double and the collective passenger travel of under 500 km should be carbon neutral. In addition, rail freight should increase by 50 % and automated mobility deployed at large scale. By 2050, the rail freight and high-speed rail traffic should have doubled and tripled, respectively. These goals are all set taking traffic during year 2015 as reference. A successful transformation of the European transport system in accordance with these long-term objectives requires an understanding of the current state-of-play of the railway market. The development on the railway market during the period 2015-2018 is covered in the Rail market monitoring report (European commission, 2021). An average annual growth for passenger and freight rail traffic in Europe of about 2.5 % and 4.1 %, respectively, is reported. With regard to the long-term development, diverging trends can be observed for passenger and freight rail transport in Europe. For the period 2005-2018, rail passenger traffic shows an upwards trend corresponding to a total increase in passenger kilometers of about 25 % whereas for freight a local maxima in ton-kilometers occurred in 2007 which was not exceeded until 2018 (European commission, 2021). In 2018 the market share for rail freight compared to other modes of transportation was 18 %. This corresponds to an increase in market share by approximately 1 % since 2009 (UIC, 2020). The increase in modal share for passenger rail traffic during the same period was below 1 % (European commission, 2021).

This moderate historical development of the railway market is to be accelerated by the significant effort on research and innovation that S2R entails. Technology development is at the centre, the opportunities of digitalisation and automation to make improvements with regard to e.g. productivity and competitiveness compared to other transportation modes, is to be utilised. But although the
impact of technological development on the future of railways will be far-reaching, its purpose to provide mobility to people and goods remains, and so does the need for humans to control the operation of the transport system. Hence, the human factors in the system in all their various aspects (e.g. human-technology interaction, professional training, etc.) need to be considered in order to ensure an efficient transition. Challenges with regard to human capital has already been reviewed in deliverables D8.1 and D8.3. The European population is declining and the age structure of employees in the rail sector is generally high. For example, Deutsche Bahn has reported a need for significant increase in new recruitments to meet the large retirements in the coming years (Metzger, 2018). The generally low attractiveness of the railway sector and related difficulty to attract new talent constitutes a complicating factor for this strive. D8.1 and D8.3 also provide a general description on how technology development is likely to effect for example job profiles and working conditions.

The introduction of automatic train operation (ATO) on mainline railways is to be regarded as one of the ultimate goals of the technology development in S2R. Therefore, the literature review contained in previous deliverables of WP8 is complemented by observations from railway lines that are forerunners in this respect. The experience from many decades of automatic train operation at several public transit system around the world is reviewed. In addition, information on current employment levels in the European railway sector and predictions on its future development contained in the work by the tender research partner TNO is described.

5.3.1 Experiences from automated rail traffic systems

Much of the technological development carried out in S2R innovation programs 2 & 5 (IP2 & IP5) has the enabling of automatic train operation (ATO) as its ultimate goal. With respect to human factors, this paradigm shift is probable to have a profound impact on the labor market both in terms of skills/qualification needs, job profiles and employment levels. Their extent, the great variety of vehicle types and the need for standards agreed on between manufacturers and over national borders, make the introduction of ATO on mainline railways more difficult compared to smaller networks such as for example public transport systems. On metro, ATO was first implemented already in 1962 (Rachel, 1962). However, this installation located in New York still required an onboard train operator to supervise the drive and to operate doors. This limited its impact on e.g. productivity and capacity. The metro in Lille, France, became the first to allow unattended train operation (UTO). It was opened in 1983 and comprised two lines and a total of 60 stations and 45 km of track (Wang, 2016). In 2016, ATO was adopted on a total track length of 780 km located in 36 different cities worldwide. At the same year, 16 % of the total metro track length in France was prepared for ATO (Observatory of automated metros, 2016). This was largest proportion of ATO metro track worldwide. The length of ATO metro track is predicted to almost triple until year 2025 compared to 2016 (Wang, 2016).

Transport systems that adopt ATO shows several advantages compared to infrastructure with conventional traffic. In similarity with metros do mainline railway transport systems typically receive public subsidies. This makes productivity, i.e. the ratio of inputs (i.e. funds) to outputs (e.g. passenger-kilometers), key in order to ensure value for the public funds. In (Cohen et al. 2015) seven different metros are asked about the additional capital cost required to obtain technology that allows ATO as compared to conventional traffic. The results indicated a cost increase in the range between 0–30 % with a significant variation between respondents and parts of the transportation system (trains, control centers and infrastructure). A study of European mainline railways concluded the number of staff per track kilometers to be an important determinant with respect to cost inefficiency (Couto et al., 2009). Andreau and Ricart have shown the availability and scheduling of drivers to be closely linked to organisational efficiency of metro systems (Andreau et al., 2016). In this regard ATO has potential

G A 7 7 7 5 1 3 P a g e 30 | 71
to deliver productivity increase through reduced labor costs. On line 14 of the Paris metro operated automatically since 1998, the operational costs are 30 % lower when compared with the conventional line (Wang, 2016). This cost cannot be directly translated into demand for personnel because of the significant difference in professional roles for ATO compared to conventional traffic. Multiskilled staff on ATO lines may be paid more than drivers or station staff on conventional lines (Cohen et al., 2016)

ATO can be viewed as a means to decouple the offered transport capacity from the access to train drivers making shorter trains that run at a higher frequency a plausible measure to increase capacity as compared to a conventional solution with longer and heavier trains that travel at increased vehicle speeds. This enables real-time adjustments of capacity by for example adding trains in response to short-term peaks in passenger demand. Several investigations have shown that an increase in train frequency allowed by ATO itself increases passenger demand (Graham et al., 2009). Other observed effects from introduction of ATO are increased reliability, energy efficiency and safety (Wang, 2016).

Chen et al. present data collected from 35 metro system operators worldwide in the ambition to assemble evidence on how automation affects for example costs and staffing (Cohen et al. 2015). Staffing levels were investigated for personnel employed at traffic control centres, at stations, on trains and roaming between stations and trains. The total number of staff working under peak hour normalised to the number of trains in service and number of stations was compared. Whereas metros with conventional traffic (personnel on trains and at stations) show values clustered around approximately 1.5, those that allow unattended train operation (no personnel on neither trains nor stations) obtained staffing per asset as low as 0.5. With regard to the median calculated for the two categories of metro systems, the largest difference in staffing levels was found to be 70 %.

According to the standard IEC-62290-1 by the international electrotechnical commission (IEC), automation grades GoA3 and GoA4 means ATO with an attendant in the passenger car performing critical functions such as supervising door closure and no need for onboard human assistance (UTO), respectively. At GoA3 the role of the driver is changed towards one that should assist passengers in order to improve their travelling experience. Andreau and Ricart observed that this made individual onboard staff member learn more tasks and performing a more multiskilled role (Andreau et al., 2010). Brandenburger and Naymann provide a description of how train operations at GoA3 can be organised together with an examination of the emerging work environment including changing professional roles as compared to those for conventional train operation (Brandenburger, N. 2019). It is proposed to establish a remote workplace for the “train operator” automatically accessible from the driverless train as soon as it reaches its operational limits.

Personal security is a main concern for metros especially during off-peak travel. For UTO at GoA4, trains as well as stations may be unstaffed which may contribute to insecurity among travellers. However, the reduced need of personnel for train operation for GoA3 and above also provides an opportunity to increase the presence of on-board personnel without increase in staff costs (Powel et al., 2016). Cohen et al. reports that several metros that allow ATO at GoA4 (UTO) are anyhow operated with attendants onboard every train (Cohen et al., 2016). This is despite that it limits the positive effect of ATO on productivity. However not explicitly mentioned in their study, the reason may be related to a reluctance among passengers to travel in trains without onboard staff.

5.3.2 Current and future employment in the European railway sector – learnings from the Human capital report series

Section 5.5.3 presents data on employment levels dissolved on professional roles related to railway infrastructure in Sweden. This detailed information is required to enable an assessment of the impact
of specific technological innovations on e.g. the future staffing need in the railway sector. Dhondt and colleagues has reviewed the state of play regarding employment in the railway sector from a European perspective (Dhondt et al., 2018a). The lack of verified statistical data on employment levels is commented. For example, the estimate of the total number of persons employed in the European railway sector spans from 900 000 to 2.3 million persons dependent on the source. In the investigation by Dhondt et al. this is handled by compiling results from different data sources. The total size of employment in the railway sector is assessed based on the Eurostat labour force survey (Eurostat, 2018). Train drivers, service personnel on trains and stations, and sales workers were estimated to comprise approximately half of the total number of personnel in the sector (Dhondt et al., 2018a). Here, train drivers also include machine operators involved with track maintenance or shunting at railway yards.

Information was also collected from the main railway companies in Europe. The French national railway company SNCF operates both passenger and freight traffic, and manages the railway infrastructure including planning, construction and maintenance. The railway network has a total track length of about 35 000 km. In 2016 the total number of employees in France was 215 000 of which approximately 25 % belonged to the infrastructure management. The state-owned railway company in Germany, DB, is responsible for a railway infrastructure approximately 10 000 km longer than that of SNCF which makes it the largest railway network in Europe. Like SNCF, the company’s commitment covers all the main functions of the railway sector. The total number of employees in Germany of year 2016 was approximately 196 000 persons of which about 27 % were related to the infrastructure management.

The Eurostat labour force survey indicates a decline in number of employees in the railway sector of about 7 % during the period 2012-2016 (Dhondt et al., 2018a). In addition to employment numbers, the Eurostat labour force survey also accounts for educational level/skills (Eurostat, 2018). According to the survey about 60 % of persons employed in the European railway sectors have an education that corresponds to upper secondary, post-secondary and non-tertiary school (ISCED 3-4). Only in job categories senior managers (exemplified by rail operations manager) and professional engineers (exemplified by mechanical engineer) do the majority of employees have Bachelor’s or Master’s degrees or higher. In 2016 approximately 16 % of employees in the European railway sector had positions that belonged to these job categories (Eurostat, 2018). Dhondt et al. also applied data from the Eurostat labour force surveys to assess the trends between 2012-2016 with respect to skills requirements (Dhondt et al., 2018a). Here a general upskilling trend is seen for all professional roles. This is despite that no significant change with respect to job profiles was observed.

TNO arranged the so-called foresight workshop to discuss skills development in the railway sector with expert representatives from the railway sector (Dhondt et al., 2018b). Employer’s organisations, trade unions, manufacturers, railway organisations and research bodies were included among the attendees. The discussion focused on a cross-section of job categories. For the period up to 2025, the participants foresaw stable or increasing employment levels for all occupations but sales personnel and train drivers. Participants also expressed a general need to improve all skills of personnel in the railway sector. More specifically the need for engineers and train drivers to develop their technical competence and communicative skills were highlighted. The distribution of personnel between the different railway job categories included in the Eurostat labour force survey showed a moderate variation during the period 2012-2016 (Dhondt et al., 2018a). This may indicate a limited previous technology uptake. During the workshop it was commented that the railway sector consists of heavy structures that react to changing demands and market conditions at a slow pace. Further, the
importance of the railway sector’s ability to compete with other transport modes for its future development was emphasised.

### 5.4 Impact of Shift2rail technology innovations on skills and job profiles

As part of a tender research project, experts at TNO and Newrail of Newcastle university identified possible skill gaps in the railway sector that may develop as a result of the work performed in connection to the IPs and TDs of S2R (Dhondt et al., 2019a). Here skill gaps are recognized as changes in skills that will not be solved without changes in current policies. To represent the spread of professional roles that exist in the railway sector, eight different occupational categories were selected based on the International Standard Classification of Occupations (ISCO) levels:

- **Rail operations manager** (ISCO-1): includes e.g. personnel at traffic control centres, railway station manager, logistics and distribution manager
- **Engineer** (ISCO-2): includes e.g. electrical, mechanical and ICT-engineers
- **Logistics engineer** (ISCO-2): ensures efficient supply chains and timely allocation of transport means and equipment
- **Dispatch worker** (ISCO-3): personnel involved with organisation and planning of shunting operation
- **Rail and train maintenance technician** (ISCO-3): includes e.g. rolling-stock engine tester, rolling stock engineering technician and track technicians
- **Rail logistics coordinator** (ISCO-4): manage shipments by rail potentially including other transport modes
- **Train attendant** (ISCO-5): manages safe boarding of passengers, travelling services, ticket inspections and
- **Train driver** (ISCO-7): includes machine operators, rail switch persons and shunting personnel etc.

The eight occupational categories above can be further divided into two overall groups; operational (rail operations manager, dispatch worker, rail maintenance technician, rail logistics coordinator, train attendant and train driver) and engineering jobs (engineer, logistics engineer) (Dhondt et al., 2019a).

In (Dhondt et al., 2019a) skills development are assessed following the distinction by the Organisation for Economic Co-operation and Development (OECD) that includes STEM (Science, Technical, Engineering, Mathematics), communicational (COMM), social (SOC) and organizational (ORG) skills:

- **STEM**: skills connected to required knowledge to perform a task
- **COMM**: skills related to reading, writing and presenting
- **SOC**: skills related to ability to build relationships with colleagues and clients
- **ORG**: skills related to planning, preparing and analysing work

The innovations that result from S2R are illustrated and tested in 42 different TDs. Dhondt and colleagues made a qualitative evaluation of the impact of each of these TDs on future skills needs in the eight selected occupational categories introduced above. In D8.1, and later expanded in D8.3, the impact of the TDs on future job profiles was presented (Metzger, 2018; Metzger, 2019). Table 2 presents a consolidation of important results from all these references and provides an overall view on the impact of S2R research and innovation activities on job profiles and skills development of the railway labor market in the future. In addition, concrete examples of innovations from S2R are taken from the so-called catalogue of solutions (Shift2rail, 2019). The S2R IPs represent development
activities that focus on different parts of the railway sector, e.g. IP2 (“Advanced traffic management and control systems”) relates to traffic planning and operation and IP3 (“Cost-efficient and reliable high-capacity infrastructure”) to infrastructure maintenance, respectively. Correspondingly, the impact on human capital of the innovations developed in the respective IPs will primarily be constrained to these different parts of the railway sector.

In (Dhondt et al., 2019a), the impact of the technology development of S2R on future employment levels is suggested for further research. However, the adoption process required for uptake of new technology is discussed. The slowing down of this process due to factors such as resistance among stakeholders in the market, competition from other modes of transportation and interaction between old and new technology is commented. It is stressed that new technology leads to a short-term increase in competence and resource need. Savings of investments in terms of increased productivity and lower personnel needs is visible only in the long term. The introduction of the signalling safety system ERTMS on the railway infrastructure in the Netherlands is taken as an example. ERTMS is required as a facilitator for future automatic train operation and transport capacity increase enabled by increased traffic density. But the retrofitting of ERTMS on existing railway lines corresponds to a significant effort associated with a large increase in staffing need. Benefits in terms of increased efficiency enabled by reduced employment levels are schematically anticipated for the period after 2030 (Dhondt et al., 2019a). With respect to associated resource needs, ERTMS has been recognised as one of the current most important current measures on the railway infrastructure in Sweden (Torstensson et al., 2021).

The implementation of new innovations in the railway system (e.g. ERTMS) occurs partly and gradually. During a long period, the railway system will contain a mixture of old and new technology and as such also require organisations that obtains competence within the new knowledge areas while skills in the traditional technology simultaneously is maintained. The need for staff whose work relates to the traditional technology diminishes only at a slow pace (Dhondt et al., 2019a). This is also commented by respondents at Trafikverket in the interviews discussed in Section 5.7.2.

Much of the development performed in Shift2Rail IP2 and IP5 is related to the long-term goal of introducing automatic train operation on mainline railways. The experience from metro systems indicates that this innovation has potential to significantly impact both employment levels and skills requirements of selected professional roles in the sector, see Section 5.3.1. In Table 2 this is illustrated by a gap in all skills areas for operational jobs such as e.g. train drivers, train attendees and train operations managers where a transformation from manual operation to different levels of assistance ranging from increased usage of IT-tools to complete automation is anticipated. Increased requirements in STEM skills are predicted for all IPs and occupational categories. This also corresponds to the general upskilling tendency discussed in Section 5.3.2 (Dhondt et al., 2018a). The change in requirements of COMM, SOC and ORG skills among railway personnel resulting from the developments in IP3 is anticipated to be moderate, see Table 2. The S2R solutions associated with IP3 are noticed to focus on design improvements of the vehicle–track system, improved condition health monitoring systems and tools for prediction of long-term maintenance. At system level, this has potential to reduce the future need for maintenance and hence contribute to more efficient and productive maintenance operation. Innovation of IP2 targets closely on specific professional roles such as e.g. train drivers. In comparison, IP3 is predicted to have a more general impact on the railway sector. This is also reflected in the interviews with representatives from railway contractors in Sweden who do not emphasize specific professional roles believed to be particularly influenced by the technological development, see Section 5.7.3.
Table 2. Overview of impact of Shift2rail technology demonstrators and innovations/solutions on future jobs and skills profiles. Consolidation of information contained in previous deliverables D8.1 and D8.3 (Metzger, 2018; Metzger, 2019), the tender research project by TNO (Dhondt et al., 2019a) and the Shift2rail catalogue of solutions (Shift2rail, 2019). =: unchanged, +: increased skills requirement

<table>
<thead>
<tr>
<th>IP</th>
<th>S2R Technology demonstrators</th>
<th>S2R innovations/solutions</th>
<th>Influenced job categories</th>
<th>Aggregation of impact on job profiles</th>
<th>STEM</th>
<th>COMM</th>
<th>SOC</th>
<th>ORG</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.2 Automatic train operation</td>
<td>19 ATO</td>
<td>Operational jobs</td>
<td>Transformation from manual operation to supervision, integration of autonomous ICT tools, improved working conditions (less stress enabled by decision-support), reduction of unexpected events.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>2.8 Virtually coupled train sets</td>
<td>20 Moving block</td>
<td>Rail operations manager, train driver, train attendant*, dispatch worker, rail logistics coordinator</td>
<td>+</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td>2.9 Traffic management system</td>
<td>21 Fail-safe train positioning</td>
<td>+</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>22 Adaptable communication system</td>
<td>=</td>
<td>=</td>
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<tr>
<td></td>
<td></td>
<td>23 Integrated mobility management</td>
<td>=</td>
<td>=</td>
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<td>Engineering jobs</td>
<td>Requirement of in-depth knowledge in traditional (e.g. mechanical, electrical and civil engineering) as well as evolving (e.g. information, communication and automation) technologies. Potentially new engineering professional roles will be introduced as results of the introduction of new innovations. Important engineering technology areas influenced by the S2R IP2 innovations are for example big data analysis, artificial intelligence, cyber security, sensing technologies, telematics, traffic management, etc.</td>
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<td>3</td>
<td>3.1 Enhanced switch and crossing system</td>
<td>24 Low cost high speed bridges</td>
<td>Operational jobs</td>
<td>Introduction of new sensor technologies for remote condition health monitoring of the railway infrastructure will reduce the need for in-field inspection. Better</td>
<td>+</td>
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<td></td>
<td></td>
<td>25 Long performing structures</td>
<td>Track and vehicle maintenance</td>
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<tr>
<td>3.2 Next generation switch and crossing system</td>
<td>26 Enhanced switches and crossings system</td>
<td>technicians, rail operations manager</td>
<td>working conditions enabled by more quiet, less polluting and covered general purpose railbound maintenance equipment. The proportion of predictive maintenance will increase with a related positive influence on working conditions by better possibilities for traffic planning. Introduction of smart maintenance tools and information systems. Long-term development from hands-on maintenance on-site towards remote operation. This will lead to an increased need for knowledge within information and communication technology.</td>
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<tr>
<td>3.3 Optimised track system</td>
<td>27 High performance wheel-rail interaction</td>
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<td>3.4 Next generation track system</td>
<td>28 Data for track circuit maintenance</td>
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<tr>
<td>3.5 Proactive bridge and tunnel assessment, repair and upgrade</td>
<td>29 Data &amp; positioning: lean tamping</td>
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<td>3.6 Dynamic rail information management system</td>
<td>30 Automation: robot platform</td>
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<td>3.7 Railway integrated measuring and monitoring system</td>
<td>31 High-pressure waterjet cutting</td>
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<td>3.8 Intelligent asset management strategies</td>
<td>32 DATA: integrated measuring system</td>
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<td>33 DATA: decision making plan</td>
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<tr>
<td>4.1 Interoperability framework</td>
<td>Seamless multimodal travel</td>
<td>Operational jobs</td>
<td>Software and apps will provide travelers with advanced functionality for e.g.</td>
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<td>35</td>
<td>Train attendant</td>
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<td>4.2 Travel shopping</td>
<td>4.3 Booking &amp; ticketing</td>
<td>4.4 Trip tracker</td>
<td>4.5 Travel companion</td>
<td>4.6 Business analytics platform</td>
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<tr>
<td>36 Travel companion- personal application</td>
<td>37 Contractor management market place</td>
<td>38 Business analytics for transportation</td>
<td>39 Interoperability framework</td>
<td>journey planning, information sharing (for example in connection to traffic disruptions) and travel shopping. Services that currently are performed manually will be moved online (e.g. ticket sales, travel shopping and ticket check). Future skills need related to the functionality of new IT tools and means to improve the traveler’s experience by enhanced service provision in connection to after-sales, travel advices and management of intermodal travelling.</td>
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**Engineering jobs**

Engineers in e.g. information and computational technology

Knowledge in information technology will become key in the development of a computational framework to support future mobility. Development of software and apps for big data management and travel shopping based on information shared by different sector actors (i.e. infrastructure managers, operators and other product and service providers)

<table>
<thead>
<tr>
<th>5</th>
<th>5.1 Fleet digitalization and automation</th>
<th>5.2 Digital transport management</th>
<th>5.3 Smart freight wagon concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>ATO</td>
<td>Obstacle detection system</td>
<td>Rail operations manager, train driver**, dispatch worker, train maintenance technician, rail logistics coordinator</td>
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<tr>
<td>41</td>
<td>Freight automatic coupler</td>
<td>Condition based and predictive maintenance</td>
<td>Transformation from manual operation to supervision, integration of autonomous ICT tools, improved working conditions (less stress enabled by decision-support), reduction of unexpected events</td>
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</table>

**Operational jobs**

rail operations manager, train driver**, dispatch worker, train maintenance technician, rail logistics coordinator

Transformation from manual operation to supervision, integration of autonomous ICT tools, improved working conditions (less stress enabled by decision-support), reduction of unexpected events

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**Engineering jobs**

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**Operational jobs**

rail operations manager, train driver**, dispatch worker, train maintenance technician, rail logistics coordinator

Transformation from manual operation to supervision, integration of autonomous ICT tools, improved working conditions (less stress enabled by decision-support), reduction of unexpected events

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</table>
### 5.4 New freight propulsion concepts

- Distributed power for long trains
- Full electric last mile propulsion
- Battery module
- Yard and network management
- Digital brake test
- Intelligent video gate
- Light thermostable wheel
- Silent wheelset
- Extended market wagon

### Engineering jobs

Engineers in e.g. mechanical, automation, computer, electrical and information technology

### Need for in-depth knowledge in traditional (e.g. mechanical, electrical and civil engineering) as well as evolving (e.g. information, communication and automation) technologies. Potentially new engineering professional roles will be introduced as results of the introduction of new innovations. Important engineering technology areas influenced by the S2R IP5 innovations for example big data analysis, artificial intelligence, cyber security, sensing technologies, telematics, traffic management, etc.

- For train attendants SOCC and ORG has been predicted to be unchanged (=) by IP2
- For train drivers STEM and ORG has been predicted to the unchanged (=) by IP5
5.5 Future competence and resource needs linked to Swedish rail infrastructure

During 2019 a research project was carried out purposes to develop a practical and useful model to predict the future need of resources and competences linked to Swedish railbound infrastructure. The work was conducted by the Swedish National Road and Transport Research Institute (VTI), in collaboration and through funding from the Trafikverket. Railbound transportation in Sweden was accounted for in a broad sense by including infrastructure managers of light-rail/tram, metro as well as railway track networks. In addition, the major railway contractors and technology consultancy companies participated in the work. To make a prognosis of future resource and competence needs, essentially two different types of information are required; (1) the future work demand here represented by the infrastructure managers’ long-term budgets and (2) the existing composition of personnel related to Swedish railbound infrastructure and their age distribution. With this as input, a model was developed that calculates the number of personnel required to perform measures towards the predicted available resources taking into account retirements and staff out- and inflows.

A prognosis of future competence needs, and the identification of potential resource gaps, requires the development of demand and supply of resources, as well as their interrelationship represented by the productivity, to be predicted over time. The analysis is made complicated by the large number of external influencing factors affecting the development in these various areas. If long-term economical cyclical factors are excluded, the resource demand coupled to rail transport is primarily determined by the extent of planned measures in railbound infrastructure and prognoses of demand for future rail transportation work. As far as this information is concerned, the conditions will differ significantly between countries in terms of both the extent of the plans and the availability of the data. As for the resource supply, according to the discussion in Section 5.3, it is influenced by for example the demographics of an aging and declining European population and the attractiveness of the railway sector. The rapid ongoing technology development has potential to make significant changes in the rail industry both with respect to the resource supply (e.g. change in job profiles) and the productivity (e.g. new methods to monitor, build and maintain the infrastructure). The current work makes a quantitative assessment of this impact on staff coupled to railbound infrastructure. This assessment is made by combining numerical prognosis results with interviews held to benefit from the experience and knowledge from the field. To this end, discussions are held with experts employed at infrastructure managers, technology consultancy companies and railway contractors to collect their views on the importance of technological development on the skill profiles of personnel in their respective segments of the railway sector.

Below, the model for prediction of future resource and competence needs is described and applied to calculate results for personnel linked to Swedish railbound infrastructure. The presentation is based on three previous published research reports (Torstensson and Hedström, 2019; Svanberg et al., 2020; Torstensson et al., 2020). However, the description in the following is a significant rework compared to the original material. Interviews conducted to discuss the impact of technological development on personnel in the studied segment of the rail sector is presented in Section 5.7. Section 5.8 presents results from the workshop held to discuss the applicability of the results obtained for the Swedish case.

5.5.1 Considered professional roles

In a scientific approach, it is important to define the domain to be studied and to identify system boundaries. In the current research work, this has posed a challenge both with respect to the budget information used to describe future needs, and the data that represent the industry’s resource and competence assets. One difficulty has been related to the close integration of the rail sector with other...
related industrial sectors. For example, technology consultancy companies are often active in several sectors such as infrastructure, structural and civil engineering. In the current work this means that, for these organisations, personnel working in the rail sector needs to be distinguished from the group of employees active in other sectors. In Sweden, Trafikverket is responsible for the long-term infrastructure planning for all transporting modes (road, rail, sea and air transport). This responsibility across transporting modes has led to a further integration also with respect to professional roles. Consequently, it has been necessary to specify a criterion to distinguish personnel with competences relevant for the current study.

The relevant professional roles for the current study have been distinguished based on the physical design of the track infrastructure. In particular, the interface between track sub- (terracing, bridges, tunnels, etc.) and superstructure (ballast, sleepers, rails, power supply system, signaling system, etc.) was used. Only personnel linked to the later is accounted for. For example, this includes several different professional roles working in the areas of track, electrical, signalling and telecommunication at railway contractors, as well as engineers at the technology consultancy companies working with the physical design in the same areas. Furthermore, the corresponding competences at the infrastructure manager has been included. The selection of professional roles was made in consultation with representatives from several different technology consulting companies, rail contractors and Trafikverket. The complete list of professional roles is found in Section 5.5.3.

5.5.2 Modelling procedure

The proposed methodology for prediction of future competence and resource needs is illustrated in Figure 1. The prognosis is performed based on the relation between work demand, represented by the infrastructure managers’ planned investments at a reference year, and the access to resources in terms of personnel with different competences. The relationship between invested cost (demands) and access to personnel (resources) is developed for each selected professional role individually. This enables the future resource and competence needs to be predicted based on the long-term budgets of the infrastructure managers and general assumptions regarding productivity and employment turnover. The age composition of personnel in the professional roles included in the study has been collected to enable a prediction of the retirements during the considered time-period, see Section 5.5.3. The analysis procedure used for the budget information is described in more detail below. Both demand (long-term budgets of the infrastructure managers) and resource (access to personnel in considered professional roles) datasets are broken down by industry segments; rail contractors, technology consulting companies and infrastructure managers, see Figure 1. Note that personnel at the railway contractors is further divided into technology areas; track, electricity, signalling and telecommunications.
At intervals of four years, Trafikverket presents a so-called National plan for the transport system (Trafikverket 2017). This report describes the proposal by Trafikverket on how the state-owned infrastructure for shipping, aviation, rail- and roadbound transportation should be maintained and developed during the coming twelve-year period. As input, the parliament sets financial limits and gives directives on priorities to Trafikverket. The national plan for the transport system gives the broad overall description of the efforts proposed to be carried out. For example, only investments that exceed 10 million euros are included. After it has been adopted by the parliament, Trafikverket is instructed to carry out the measures specified in the report. As part of this work a so-called Action planning is developed. This accounts for the coming six-year period and contains thousands of individual measures with a wide spread both in terms of location in the country and type of work. Trafikverket has supplied the current project with data from their action planning and this forms basis for the prediction results of future competence and resource needs presented in Section 5.5.4.

The current National plan for the transport system contains rail-related measures to the extent of approximately 28 billion euros (Trafikverket 2017). This includes individual mega-projects such as the construction of 160 km new mainline railway track between Stockholm and Linköping (the East link project) as well as thousands of minor measures. In order to make the prediction model practically usable is has been necessary to aggregate this information. To this end, so-called action categories has been inherited from Trafikverket. By introducing 16 action categories it has been possible to account for more than 90 % of the total invested railway related cost in Trafikverket’s action planning. The different action categories are described in Table 3.

Measures that belong to a common action category are modelled with a similar distribution of the planned invested cost across segments of the railway sector. This is prescribed by the action model.
associated with each action category, see Figure 2. The action models have been created based on the historical outcome of all measures ordered and invoiced by Trafikverket during the period 2010 – 2018. Details are found in (Torstensson and Hedström, 2019).

Table 3. Description of action categories included in the prediction model.

<table>
<thead>
<tr>
<th>Action category</th>
<th>Example of measures</th>
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<tbody>
<tr>
<td>Double track</td>
<td>Construction of new multi-track infrastructure</td>
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<tr>
<td>Maintenance</td>
<td>Infrastructure maintenance</td>
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<tr>
<td>Track</td>
<td>Track renewals</td>
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<tr>
<td>Traffic operation</td>
<td>Includes measures that focus on the signalling and telematics areas</td>
</tr>
<tr>
<td>Signalling</td>
<td>Renewals of interlocking systems, measures related to level crossings</td>
</tr>
<tr>
<td>Meeting stations</td>
<td>Construction of meeting stations and turning tracks</td>
</tr>
<tr>
<td>Single track</td>
<td>Construction of new single-track infrastructure</td>
</tr>
<tr>
<td>Power supply</td>
<td>Measures related to power supply; renewal of substations and inverters</td>
</tr>
<tr>
<td>Electrical measures</td>
<td>Renewal of IT-equipment, mobile electricity generators, etc. Measures related to work on interlocking systems</td>
</tr>
<tr>
<td>Overhead catenaries</td>
<td>Upgrading of existing and construction of new overhead catenary systems</td>
</tr>
<tr>
<td>Stations</td>
<td>Construction of new and re-building of existing stations</td>
</tr>
<tr>
<td>Operation</td>
<td>System-wide measures related to operation</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>Equipment for transmission and receiving of telecommunications data</td>
</tr>
<tr>
<td>Change of speed</td>
<td>Measures related to change of speed on existing infrastructure</td>
</tr>
<tr>
<td>Switches and crossings</td>
<td>Change of switches and crossings</td>
</tr>
<tr>
<td>Level crossings</td>
<td>Measures related to level crossings</td>
</tr>
</tbody>
</table>
Figure 2. The sum of Trafikverket’s planned investments on railway infrastructure during the period 2018 – 2029 versus action categories. The single most expensive measure in each action category is outlined in blue colour. Example cost distributions across railway industry (action models) segments of measures in action categories; Double track, Signalling and Switches & crossings are outlined in the top of the figure.

5.5.3 Available resources and competences

The number of persons occupied in the sector related to infrastructure for railbound transportation in Sweden has been surveyed. Only personnel in professional roles according to the definition in Section 5.5.1 was included. A detailed presentation of the research method and results are found in (Svanberg et al. 2020).

Information on number of personnel and age distribution in different professional roles were collected from 16 different partner organisations including 4 infrastructure managers, 4 track contractors and 8 technology consultancy companies. The infrastructure managers included in the study were Trafikverket and the public transport in cities Stockholm, Göteborg and Norrköping. Personnel at Trafikverket made up approximately 97 % of the total number of working staff at infrastructure managers. Personnel employed at companies that were not included in the study was estimated based on information in the public company index (Svanberg et al. 2020). The infrastructure managers and technology consultancy companies were estimated to accommodate approximately 14 % and 23 % of the workforce, respectively. The largest proportion of staff corresponding to about 62 % was employed at railway contractors.
In collaboration with partners representing different segments of the rail sector 58 different professional roles to include were identified. The distribution of this personnel over the different segments in the part of railway sector linked to rail infrastructure is shown in Figure 3. The total number employees amount to 5,865 persons; 3,654 persons at railway contractors, 1,377 persons at technology consultancy companies and 834 persons at the infrastructure managers (811 persons were employed at Trafikverket). The personnel at the railway contractors are further divided into track, electrical, signalling and telecom technology areas, see Figure 3.

Figure 3. Distribution of personnel in considered professional roles over different segments (railway contractors, technology consultancy companies and infrastructure managers) of the part of the railway sector linked to infrastructure for railbound transportation in Sweden. The working staff of railway contractors is further divided into track, electrical, signalling and telecom technicians.

Figure 4 presents the distribution of personnel over the 58 professional roles included in the study. The workforce at the three segments of the railway sector (infrastructure managers, technology consultancy companies and railway contractors) is outlined in different colors. As shown in Figure 3 approximately 62% of the total workforce is employed by railway contractors. The five professional roles at railway contractors with the largest number of personnel (track technician, signalling technician, electrical technician, team leader and track welder) together make up almost 45% of the total workforce in the sector. At technology consultancy companies signalling planners represent the largest personnel category. The considered professional role with the largest number employees at infrastructure managers is project leaders. Employees in this occupation at infrastructure managers and technology consultancy companies together make up 471 persons which in terms of number of persons corresponds to the fourth largest professional role included in the study. A brief description of the working tasks and skills requirements associated with the eight occupations of the sector with the largest number of personnel follows below:

**Track technician, 806 persons, ISCED level 0-2:** Employed at railway contractors. Work with maintenance, renewal and construction of new railbound infrastructure. Common tasks include renewal of switches and crossings and main line track, clearing of snow and vegetation, and correction of track alignment.

**Signalling technician, 604 persons, ISCED level 0-2:** Employed at railway contractors to ensure the functionality of the railway signalling system. The main work concerns maintenance, troubleshooting and construction/installation of new equipment linked to the signal systems.
Electric technician, 499 persons, ISCED level 0-2: Employed at railway contractors with replacement of old contact wires and catenary systems, as well as to maintain and repair existing equipment.

Project leader, 471 persons, ISCED level 3-4: Employed at infrastructure managers and technology consulting companies. The project leader is responsible for the delivery of the project to the client. The project leader decides on actions and use of resources.

Team leader, 461 persons, ISCED level 0-2: Employed at infrastructure managers. Leads and coordinates a team of technicians of different areas of competence to perform measures in the infrastructure according to the project agreement made with the client.

Welding technician, 272 persons, ISCED level 0-2: Employed at railway contractors and working in teams together with track technicians. The welding technicians performs maintenance, renewal and new construction of tracks for railway, subway and tram traffic.

Signalling planner, 263 persons, ISCED level 5-6: Employed at technology consulting companies. The signalling planer works as part of a team that constructs and develops two- and three-dimensional construction drawings for railway new signalling systems.

Technology specialist, 198 persons, ISCED level 5-6: Employed at infrastructure managers. The technology specialist supports projects with specialist knowledge in different railway specific areas, e.g. design and maintenance of track superstructure. The specialist has an overall responsibility of the associated area of expertise at the infrastructure manager.

As part of this mapping effort also data on age were collected. In general, a shift with large numbers of personnel in the younger age categories is seen for the technology consultancy companies. The railway contractors show a lack of personnel with medium experience in the age category between 40-49 years. This is for example observed for the three professional roles with the individually largest number of personnel in the railway sector; track, signalling and electric technicians. Further, for non-destructive testing technicians, authorized electric technician and welding managers the railway contractors do not have any personnel in the age category 20-29 years. However, it should be noticed that the total number of persons in these professional roles is below 15 which makes the results sensitive to transfer of personnel.
Figure 4. Number of persons employed in the 58 selected professional roles in the sector coupled to infrastructure for railbound transportation in Sweden. Personnel at infrastructure managers, technology consultancy companies and railway contractors is outlined in different colors. Professional roles with fewer than 40 persons are outlined with grey foreground.
5.5.4 Prediction of future competence and resource needs

The future competences and resource need in the Swedish sector linked to railbound transportation is predicted. The results are calculated based on the collected information about number of personnel and age distribution in the selected professional roles, see Section 5.5.3. The demand for work is represented by the long-term budget planning. With regard to budget, the total cost of measures planned by Trafikverket exceed those of the other infrastructure managers by more than 15 times. In terms of track length, the corresponding factor instead is 36. The prediction results presented below are based on the follow governing assumptions:

- The prognosis is made with the situation of year 2019, when the mapping of available resources and competences was performed, as reference.
- In each of the three segments of the sector (i.e. infrastructure managers, technology consulting companies and railway contractors) the composition of personnel is assumed to remain constant during the prognosis period.
- The action models that prescribes the distribution of costs associated with measures planned by the infrastructure managers on the sector segments are kept constant for the prognosis period. For more information on the action models see Section 5.5.2.
- The prognosis is made with an assumed increase in productivity by 0.5 % per year and an inflow of personnel by 2 % per year. The same estimations are used for all sector segments These assumptions are based on a report by the Swedish construction federation (Sveriges Byggindustrier 2018).
- The retirement age is set to 65 years which corresponds to the average retirement age in Sweden.

Figure 5(a) and Figure 5(b) show the long-term budget and the corresponding predicted resource need for the period 2019-2025, respectively. Results are shown broken down on action categories. The annual cost for planned measures is seen to increase for the studied period, see Figure 5(a). This is noted to be predominantly determined by the cost increase in action category Double track. To this category belongs the construction of new railway infrastructure such as for example the “East link project” Stockholm – Linköping (approximately 6 BEUR) and the “West link project” in Göteborg (approximately 2.5 BEUR). The action category that has the second largest cost is Maintenance with a planned total budget of approximately 3.4 BEUR. Figure 5(b) shows how the predicted resource needs relate to the action categories. Note that these results apply to all personnel included in the study (prognosis results presented for sector segments separately follow below). By comparison of Figure 5(a) and Figure 5(b), large differences in importance of individual action categories in terms of budget and resource needs are seen. For example, 56 % of the total budget at year 2025 is associated with the Double track action category whereas it requires only 35 % of the total need for personnel at the same year. This is due to the relatively small cost share that is spend on personnel in professional roles considered in the current study in this action category, see Figure 2.
Figure 5. The infrastructure manager's long-term budget (a) and the corresponding predicted need for personnel (b) during the period 2019-2025. Results are presented for the different action categories separately.

A gap analysis is performed by assessing the difference between future demand for, and access to, resources. Results are predicted for each of the 58 included professional roles (outlined in Figure 4) individually. However, to improve and simplify their interpretation predictions are aggregated into the three sector segments infrastructure managers, technology consultancy companies and railway contractors. The latter’s personnel are further divided into technology areas track, electric, signalling and telecommunication technology.

The workforce at year 2019 of 5 865 persons is predicted to increase to 7 032 persons by the year 2025. This corresponds to an increase in number of personnel in the entire sector related to infrastructure of railbound transportation of approximately 20%. However, the development in the difference sector segments shows large differences. Until 2025 the demand for personnel at infrastructure managers, technology consultancy companies and railway contractors are predicted to increase with 45%, 42% and 6%, respectively. Apparently, according to the prognosis, the increase in resource need will primarily affect officials at the infrastructure managers and consultancy companies. At year 2025 the largest resource gap is estimated for Signalling planners at the technology consultancy companies.

The maximum resource gap during the studied period 2019-2025 is predicted to occur at year 2021 and considers primarily personnel in the track technology area employed at the railway contractors, see Figure 6. Lack of personnel is predicted to occur mainly in the professional roles Track technicians, Team leaders and Welding technicians. This local peak in resource need at year 2021 is for example related to track replacement works on the Northern main line and the construction of the Northern bothnia line. Figure 6 shows another local peak in resource need that occurs at year 2023 for personnel in the electric technology area at railway contractors. The primarily affected professional roles are Electric technicians, Team leaders and Power technicians. The measures that drive this resource need are mostly the replacements and renewals of overhead catenary lines on the Western main line commissioned by Trafikverket. After an initial rapid increase in lack of resources until 2020, the gap in
personnel in the Signalling technology competence area employed at railway contractors is predicted to level out during the subsequent period, see Figure 6.

Figure 6. Prognosis of demand, access and gap of personnel in the sector linked to infrastructure for railbound transportation during the period 2019-2025. The top figures outline the prognosis results for the track, electric and signalling technology areas of the railway contractors separately.

5.5.5 Prediction results for Trafikverket and railway contractors broken down on action categories

Approximately 14% and 62% of the personnel in professional roles accounted for in the current study are employed at Trafikverket and railway contractors, respectively, see Section 5.5.3. Figure 7 shows an estimation of how these personnel distributes on the different action categories accounted for by the model for prognosis of future competence and resource needs. The action categories are outlined in Table 3. The corresponding results calculated for railway contractors are found in Figure 8. It should be noticed that data from the mapping do not specify within which action categories the employees are occupied. Instead, Figure 7 and Figure 8 are obtained by numerical prediction. This means that these results should be used for relative comparison between staffing in different action categories rather than to assess the absolute number of persons in specific action categories. It is noticed that approximately 62% of the personnel in considered professional roles at Trafikverket is engaged in work associated with action categories Double track (e.g. construction of new railway infrastructure) and Maintenance. For railway contractors action, category Maintenance is noticed to be the most important with regard to staffing. This is particularly prominent for professional roles in the track technology area, see Figure 8.
Figure 7. Estimated distribution of personnel with railway specific competence at infrastructure managers over action categories. Prediction performed for year 2019.

Figure 8. Distribution of personnel employed at railway contractors with competence in the areas of track, electric and signalling technology over action categories.

5.6 Railway specific competence at Trafikverket

Trafikverket is responsible for the strategic long-term planning of the state-owned infrastructure for road, rail, waterway and aviation transport in Sweden. In addition, operation and maintenance of the road and rail infrastructure belongs to the authority’s responsibilities. The number of personnel with railway specific competence according to the definition outlined in Section 5.5.1 and their distribution among Trafikverket’s different business areas is outlined in Figure 9. Business areas Maintenance, Investment and Major projects are noticed to hold staff in professional roles that require specific competence linked to the track superstructure. For a complete list of included professional roles see
Figure 4. Based on the interviews held with selected experts at Trafikverket described in Section 5.7.2 the impact of technological development is forecasted to primarily address employees within business area Maintenance.

Business area Maintenance is instructed to conduct an efficient asset management that adopts maintenance strategies that takes into account the total lifetime of the railway infrastructure. The business area is also responsible for the development and technical management of all different systems included in the infrastructure (e.g. signalling system, catenary system, track superstructure, etc.). The organisation of business area Maintenance into several different divisions is presented in Figure 10. At Technology and environment, the management and development of all technological systems and components in the track infrastructure including track superstructure, power supply, signalling and monitoring systems are performed. This includes for example long-term strategies for how to introduce and integrate new technologies in the existing infrastructure as well as future working procedures and software platforms to be used at Trafikverket. At Railway systems, strategies for how to maintain the railway track infrastructure are developed. Moreover, the division is responsible for the condition monitoring of the infrastructure and to ensure that it meets requirements with respect to its functionality. The five maintenance regions procure, leads and monitors...
maintenance and (re-)investment activities assigned by the Railway systems division. The maintenance regions are responsible for collecting the necessary data to ensure that Trafikverket always has an accurate understanding of the state of the infrastructure. The maintenance regions also support Railway systems in their work with the long-term maintenance plan. Table 4 shows the professional roles of personnel with railway specific competence employed at the relevant divisions of business area Maintenance. A principal difference is noticed between professional roles of employees at the Maintenance regions compared to Railway systems and Technology and environment where the latter two emphasis engineering and technical skills whereas the former has an operational organisation.

![Figure 10. Organisation chart of business area Maintenance at Trafikverket. Number of persons with specific competence linked to track infrastructure are outlined for Maintenance regions and the Railway system and Technology and environment divisions.](image)

### Table 4. Personnel with railway specific competence in business area Maintenance at Trafikverket. Distribution of personnel over professional roles and divisions

<table>
<thead>
<tr>
<th>Professional roles</th>
<th>Maintenance regions (number of persons)</th>
<th>Railway system (number of persons)</th>
<th>Tech. and environ. (number of persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech. specialists, investigators, analyst</td>
<td>35</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Railway and technology engineers</td>
<td>21</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Asset managers</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National coordinators</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project leaders</td>
<td>59</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Maintenance and project engineers</td>
<td>71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspectors</td>
<td>33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.7 Impact of S2R technological innovations on personnel in the Swedish rail sector

The prognosis results presented in Section 5.5 is used as starting point for a discussion about the impact of technological development on the future resource and competence needs in the Swedish sector for railbound transportation. The transferability of the results and comments made with respect to the Swedish rail sector to other European countries has been assessed in a workshop reported from in Section 5.8.

The results in Section 5.5.2 are obtained based on known future demand, i.e. infrastructure managers’ long-term budgets, and change in resource supply, i.e. changes in working staff due to for example retirements. As already discussed, these two variables are related by the productivity. The technological development with new innovative solutions for how to build, operate and maintain the railbound infrastructure, may influence both the competence profiles of personnel and the productivity, hence affecting two separate variables of the model. Potentially, the development may involve major upheavals in the labor market with structural changes in the different actors’ business operations and associated changes in composition of personnel as well as the introduction of completely new professional roles. These topics are inherently difficult to account for by prediction models and therefore emphasises the importance of conducting interviews to make use of the experience of expert representatives from the various actors in industry.

Interviews have been held with a total of 10 persons employed at Trafikverket and at the three major railway contractors active in Sweden. In addition, a railway contractor that manufactures railbound track machines was included. The interviews had a semi-structured character and were based on the following principal question:

- How will technological development influence on resource and competence needs during the coming 10-years period?

The interviews began with a brief presentation of the overall results in Chapter 5.5 adjusted to suit the respondent’s employer being either Trafikverket or a rail contractor. The composition of professional roles at Trafikverket and railway contractors, respectively, was described based on the discussion in Sections 5.5.3 and 5.6. The material for the interviews with the railway contractors also outlined examples of new working methods, machines and tools that are in a introductory stage or are likely to become introduced on the railway market.

Below, comments from the interviews are presented for Trafikverket and the railway contractors separately. The chapter begins with general interview comments common for both actors.

5.7.1 Sector-wide interview comments

Since the incorporation of the production unit in 2010, Trafikverket is purely an asset manager that conducts investments, re-investments, maintenance and monitoring of its infrastructure under the law of public procurement. This specifies lowest price as selection criterion, provided that the conditions outlined in the tender documentation are met. Maintenance is performed as part of 34 separate so-called base maintenance contracts delimited to specific geographical regions in Sweden. A basic question in this process regards the distribution of risk between the client (Trafikverket) and the supplier (e.g. railway contractor) which in turn determines the level governance required in the tender document by the client. To this end Trafikverket has the choice either to use traditional contracts under which the railway contractor performs measures in accordance with technical instructions provided by
Trafikverket. Alternatively, so-called design and built contracts are used with a corresponding shift in responsibility and risk, but also initiative to develop the business, from the client to the supplier.

To create fair competition between potential tenders, Trafikverket rarely specifies the type of equipment/machines to be used by the contractors in their contracts. In (SOU 2015:42) this procedure is believed to give railway contractors weak incentives to invest in efficient machines which in turn influences productivity and subsequently traffic capacity. Several comments made during the interviews with representatives from both Trafikverket and the railway contractors were related to this question. In general, the respondents regarded the impact of technological development on the Swedish rail sector during the previous 10 years period as moderate. For the railway contractors to justify investments in heavy track machines, a long-term high occupancy is required. In this regard, the respondents at the railway contractors comment the time limit of the base maintenance contracts to between 5-7 years as insufficient.

The respondents relate the slow introduction of technological innovations in the rail sector with the limited size of the Swedish rail market and the thereby low return of investments. According to comments made during the interviews, the long-term trend in the sector points towards a larger involvement of labor-intensive methods at the expense of productive heavy track machinery. Railway contractors prioritise simple and cheap machines at the expense of effectiveness.

5.7.2 Respondents at Trafikverket

Four persons employed at Trafikverket business areas Maintenance and Investments were interviewed. These persons were selected based on recommendations from initial discussions with a larger group of employees at the authority and hold professional roles with managerial, coordinating or technological specialist responsibilities. Results from the interviews indicate two main consequences that are expected as a result of the technological development; (1) change in competence profiles of current and introduction of new professional roles and (2) increase in efficiency/decrease in staffing requirement. Comments received during the interviews are summarised below.

Trafikverket is confident in the ability of digitalisation to improve the quality and efficiency of the maintenance work on its 14 200 km long railway infrastructure. Activities are ongoing at the authority to increase the use of big data analytics and artificial intelligence in the asset management and condition state monitoring. Digitalisation is also believed to support increased pro-activity in the maintenance planning. In the 1990s, the forward maintenance planning spanned one year. Today, the maintenance plan is valid for a four-year period and according to one respondent it is likely that it will be extended to six years in the future. This would enable an improved coordination and dialog with industry (traffic operators, railway contractors, etc.) and educational environments (e.g. to address gaps in resources and competences).

Digitalization will convey the introduction of smart connected components in the track infrastructure that continuously communicate data on their status and environment. In this regard, an important task for Trafikverket is to establish a safe, robust, reliable and forward-looking framework to collect this information. Subsequently, this data will constitute the input to software tools used in the monitoring, operation and long-term planning of infrastructure maintenance. According to the discussions during the interviews, personnel at business area Maintenance divisions Railway system and Technology and environment (see Figure 10) are directly involved in this development and will also be subjected to new competence requirements as consequence. The introduction of new professional roles such as data strategists, data stewards and data engineers are foreseen. In parallel with this increased demand
for personnel and competence, competence profiles of existing professional roles will shift towards data science. This development regards technology specialists, analysts, inspectors and engineers at the current divisions, see Table 4. In total this subordinate consists of approximately 150 persons or approximately 19% of the personnel at Trafikverket with railway specific competence.

The respondents refer to the length of Trafikverket’s track infrastructure and emphasize that there will always be a large spread in maturity of the technology used in the design at different locations. Trafikverket uses a system of six different so-called maintenance levels with different requirements on the railway contractors for example with regard to inspection intervals, quality and extent in performed measures. It is part of a cost-effective long-term maintenance strategy that the track standard and maintenance status is allowed to vary between railway lines. As a consequence, while the organisation adopts new competence in data analytics as described above, knowledge about old technology need to be kept. Respondents refer to the general difficulties of the railway sector to attract new and retain talent. Potentially this can lead a development where it becomes more difficult to maintain competence in outmoded technology than to attract personnel with knowledge in new technologies such as for example big data analytics and artificial intelligence (AI).

Maintenance and reinvestment measures commissioned by division Railway system are executed by Trafikverket’s Maintenance regions. In the opposite direction, Railway system does the long-term maintenance planning based on suggestions from, and information collected by, the Maintenance regions. In this way, the personnel at the maintenance regions constitutes a link of the entire business area Maintenance to Trafikverket’s physical railway infrastructure. Inspectors employed at the Maintenance regions follow-up maintenance and reinvestment measures so that the production by railway contractors is in accordance with what is specified in the contracts. This means that Inspectors spend a significant amount of their working time at construction sites out on track. New tools and methods resulting from the technological development is anticipated to improve the efficiency this work. This includes for example new methods for condition monitoring (e.g. based on data collected by infrastructure components, passing traffic, drones, etc.) and remote inspection. Future possibilities for rationalization, but also need to accommodate new knowledge in for example data analytics and remote inspection, are mentioned. This is believed to affect the professional roles Inspectors and Maintenance and Project engineers. All together the personnel in the current professional roles constitutes approximately 12% of all employees with railway specific competence at Trafikverket.

5.7.3 Respondents at railway contractors

Interviews were held with representatives from the three major railway contractors in Sweden: Infranord, NRC Group AB and Strukton rail AB. Together their working staff make up approximately 77% of the total number of employees of the current sector (Svanberg et al. 2020). These companies often employ smaller companies as subcontractors so their joint market share is probably larger. The respondents held positions as responsible for business development and managers for human resources. In addition, the heavy track machine developer and manufacturer Railcare group AB participated in the interviews. Questions were shared with the respondents before the interviews were conducted. Below comments from the respondents are summarised for the different questions covered separately.

- What do you think will be the main challenges for your business during the 10-years ahead?

The high traffic intensity and related decrease in availability of time slots to perform maintenance measures in track is mentioned. Railway contractors experience increasing difficulties to obtained access to the infrastructure. The long planning horizon demanded from the infrastructure manager for
coordination with traffic operators is challenging. Applications to obtain access to the infrastructure need to be submitted to Trafikverket 30 weeks in advance.

The large fleet of old heavy railbound working machines needs to be updated and renewed. This is partly to reduce environmental emissions and by that improve the work environment (noise and emissions). The generally low profitability of the industry reduces the financial headroom for such an effort.

Challenges coupled to human resources are raised. The limited time available to perform measures in track affects safety of their personnel negatively. The consequences from mistakes can become fatal. Other challenges mentioned regards the age structure of personnel being generally high, and that female technicians are almost completely lacking. These are not characteristics perceived as attractive when career opportunities are considered. It is commented that assignments are rejected due to lack of resources. In turn this increases the involvement by subcontractors. The issue related to competence and resource needs is exacerbated by the fact that, in general, about 5 years of professional experience is required for personnel to develop good problem-solving skills.

- In a historical perspective, what impact has technological development had on your business during the past 10-years period?

The technological development in the area of information and communication technology (ICT) has had the greatest impact on the railway contractors’ business during the past 10-years period. This has involved software tools that facilitate coordination of complex tasks potentially involving personnel from several different technology areas. Furthermore, the developments have made technical information on e.g. the infrastructure design always accessible, also in-field. New methods for remote inspection and condition health monitoring by instrumented vehicles or by e.g. drones have been introduced and adopted by the sector.

The recent historic trend in Sweden has led from specialized and highly productive heavy railbound working machines towards more labor-intensive working methods using lighter road- and trackbound excavators. This increases the utilisation rate of the machines as they can be used on both roads and tracks. To a certain extent, this trend takes place at the expense of the quality of the work performed in track. The development has been exaggerated by the evaluation process of tender contracts which promotes bids with lowest price without taking into account quality.

- How do you think that technological development will affect your business during the coming 10-years period?

Digitalisation will have a large impact on railway industry. The vision about the “connected infrastructure” will become real during the 10-years ahead. The many different data sharing systems of Trafikverket will merge into one common and complete IT-system. Moreover, development of tools for operational planning that accounts for influencing factors related to for example traffic, staffing, working machines and material are anticipated. These IT-systems will be fed in real-time with data from the connected smart railbound infrastructure as well as instrumented vehicles.

New methods for remote and automated inspection and monitoring of infrastructure are believed to become widely adopted by industry. As a result of this generally increased focus on collection and sharing of data, railway contractors foresee a development of their business to provide services with a larger knowledge content. The respondents predict the responsibility of railway contractors to gradually increase to also include long-term strategic maintenance planning. This will bring a
restructuring of the current sector towards a significantly greater content of engineering competence among their personnel.

More accurate simulation models for prediction of long-term mechanical degradation of vehicles and tracks provides opportunity for a better share between corrective and predictive maintenance as well as improved operational planning with traffic operators. In this regard, one respondent expresses that the solution of today’s poor foresight of infrastructure managers and railway contractors is key to bring about an improvement of future railway maintenance in Sweden.

- What determines the extent to which your company chooses to introduce new technology?

According to the respondents, this is to large extent governed by the infrastructure managers through the design of their maintenance contracts. The railway contractors are willing to take greater responsibility for the strategic maintenance planning. Trafikverket needs to introduce incentives in the maintenance contracts to encourage such a development. This can for example be accomplished by introducing quality parameters in the tender evaluation process.

A large commitment in research and development presupposes good profitability. This is not a prominent characteristic of the railway contractor business in Sweden.

The coupling between maintenance and reinvestments is also commented. Maintenance activities are aimed to maintain the track status whereas reinvestments are conducted to improve the track state. Railway contractors would like an involvement also in the planning of reinvestments. Without this engagement, the railway contracts risk becoming passive.

- How can the conditions for railway contractors to take advantage of new technology be improved?

The importance of the tender evaluation process at Trafikverket is emphasized. When the use of new technology or more productive working machines is rewarded, this development will also take place in field. To encourage technological development, it is suggested to allow railway contractors to use resources coupled to the base maintenance contracts to engage in research and development.

Support from Trafikverket is necessary to drive development of advanced technologies such related to for example robotisation and automation. However, the development of for example new tools for railbound excavators and hand-held machines can be done by the industry on its own.

- How will technological development affect the composition of competence among your personnel during the coming 10-years period?

A common predict from all interviewed company representatives is that the sector is undergoing a significant restructuring that will lead in the direction of increased engineering capacity for example in the areas of advanced analysis, simulation and information technology. This is believed to have a major impact on the composition of competence among the companies’ personnel during the 10-years ahead.

In parallel with the development towards increased STEM-capabilities among the railway contractor’s personnel as described above, a change in the opposite direction is anticipated: a de-professionalisation of technicians. Access to easy-to-understand instructions and smart, partially automated tools will partly reduce the requirements on technicians that carry out measures on track. In connection to this it is commented that the development of generally applicable working machines
(e.g. excavators able to use both on roads and rails) corresponds to a development towards more generalised competences among technicians. However, these effects are not anticipated be profound already in 10-years foresight.

The implementation of the European Railway Traffic Management System (ERTMS) is a large effort that requires significant resources in the signalling technology area at railway contractors. To develop these skills and acquire enough resources that meets the expansion rate at which infrastructure managers likes to introduce ERTMS on their networks constitutes a challenge.

5.8 Transferability to other EU countries – workshop on future skills and competences

The results obtained for the investigation of the Swedish railway sector were discussed in a workshop held on 2021-03-11. The abstract and agenda from the workshop are found in Annexes A and B, respectively. Dr. Fabien Létourneaux of SNCF was host for the event. Docent Peter Torstensson of the Swedish national road and transport research institute (VTI) presented the results for the investigation of the Swedish case described in Sections 5.5-5.7. Professor Steven Dhondt of TNO in the Netherlands who acted main author of the human capital report series produced as part of a tender research project, and Dr. Reem Hadeed of Aston University in Birmingham, UK, involved in the ongoing research project Astonrail (Advanced approaches and practices for rail training and education in railways) held invited speeches, see the agenda in Annex B. In addition, Barbara Grau of SNCF and Vladyslav Nedaviny of DB presented an overview (track length, amount of traffic, distribution of personnel, etc.) of the track network managed by the organization that they represent, respectively. About 1 h of the agenda was dedicated for discussion. This was moderated by Peter Torstensson, VTI, and based on the questions used in the interviews with the railway contractors described in Section 5.7.3. In total the workshop had 17 attendees representing UIC, the infrastructure managers SNCF (France), DB (Germany), Trafikverket (Sweden) and ProRail (Netherlands) and universities/research institutes Aston (UK), TNO (Netherlands) and VTI (Sweden).

Professor Dhondt based his presentation on the material published as part of the human capital report series in part reviewed in Sections 5.3.2 and 5.4. His presentation held at the workshop included a discussion about challenges and uncertainties associated with research that involves predictions of skills development. For example, the implementation face of new technologies often requires significant investments that in the short-term increase employment levels related to manufacturing and construction. This requires detailed data on the long-term budget planning of e.g. infrastructure managers to be accounted for which was not available as part of the human capital report series. It needs also to be considered that railways will always represent a mixture of technologies from different eras and hence a specific technology will never be implemented consistently on a complete mainline railway system. Professor Dhondt presented predictions on development of employment levels during the period up to 2024. These forecasts only accounted for the impact of S2R technological innovations and indicated declines in employment levels in the range between 2 – 13 %. To contrast these results, predictions made as part the so-called Foresight report commissioned by the S2R JU were presented. Here, the minimal impact scenario predicts approximately stable number of personnel in the railway sector whereas other scenarios forecast a significant increase in employment levels. Professor Dhondt comments that organisations usually emphasise increased future skills requirements and seldom the opposite. Moreover, barriers for adoption of new technology are reflected on. The importance of national regulations and the political support for investments are commented.
Barbara Grau and Vladyslav Nedaviny present key figures for SNCF and DB, respectively. The railway infrastructure in France is managed by SNCF Réseau whose commitment includes maintenance of existing network as well as planning, design and construction of new track. In addition, SNCF Réseau is responsible for traffic management and provision of network access. DB Netz AG is the entity of DB assigned with the corresponding role in Germany. Key figures of SNCF Réseau, DB Netz AG and Trafikverket are summarised in Table 5. The commitment of Trafikverket in relation to Swedish transportation infrastructure differs in many ways compared to that of DB and SNCF. Trafikverket manages infrastructure for both road- and railbound transportation. Moreover, Trafikverket neither designs, constructs or maintains the infrastructure in-house. According to Barbara Grau, approximately half of the total number of employees at SNCF Réseau is involved with construction and maintenance of track infrastructure. The corresponding estimate presented for the Swedish railway sector is 62 %, see Figure 3. However, the later estimation does not include personnel at Trafikverket with managerial positions or involved in the traffic operation.

In the interviews with representatives from the Swedish railway sector the impact from technological development during the past 10-years period was regarded as moderate, see Section 5.7. The workshop attendee from DB did a similar assessment regarding the historical development related to railway infrastructure in Germany. Both DB and SNCF believe that the development of tools for condition health monitoring and information management are the main results from the technology development during the previous 10 years. DB also highlights their work with standardisation of components and processes.

The technological development in the area of information and communication technology (ICT) has had the greatest impact on the railway contractors’ business during the past 10-years period. This has involved software tools that facilitate coordination of complex tasks potentially involving personnel from several different technology areas. Furthermore, the developments have made technical information on e.g. the infrastructure design always accessible, also in-field. New methods for remote inspection and condition health monitoring by instrumented vehicles or by e.g. drones have been introduced and adopted by the sector.

Anticipated challenges during the coming 10-years period were discussed. Both DB and SNCF highlight the demographic challenge. The age structure of their personnel is generally high and the interest of pursuing a career in the railway sector low. This is particularly true for women that today constitutes only 15 % of the total number of employees at SNCF Réseau. DB particularly emphasises that railway infrastructure constitutes a mixture of technologies that belong to different time eras. The innovations from S2R constitute the next contribution to this long-term process. For the infrastructure managers to simultaneously attain competence in outdated and future technologies is challenging. The same comment was made in the interviews with Trafikverket, see Section 5.7.2. In the interviews with railway contractors in Sweden profitability was referred to as a challenge and as well limiting with respect to the companies’ abilities to engage in research and development. In relation to these issues, the comparison between conditions in the Swedish railway sector and those of Germany and France lags since the current business areas of DB and SNCF are not exposed to competition.

For the Swedish case, the expectations of the railway sector on how technological development will impact their businesses during the coming 10 years can be summarized as continued utilisation of the possibilities enabled by digitalisation, see Section 5.7. This includes new tools for information management, condition health monitoring and maintenance scheduling. According to the discussions during the workshop, DB and SNCF foresee a similar development. DB highlights their ongoing
significant investment related to the upgrading to digital interlocking systems. This is one step in the establishment of a signalling safety system that is common to Europe (ERTMS) and prepared for future automatic train operation. DB emphasises in particular the significant educational and training effort of current staff related to this expansion. SNCF points to the development of digital twins as a key to make future railway maintenance more efficient by improved abilities for strategic maintenance scheduling and planning.

Table 5. Key-figures obtained for year 2017 of SNCF Réseau, DB Netz AG and Trafikverket.

<table>
<thead>
<tr>
<th>Company</th>
<th>Length of infrastructure [km]</th>
<th>Number of personnel</th>
<th>Annual passenger-km [10^9]</th>
<th>Annual tonne-km [10^8]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNCF Réseau</td>
<td>29 900</td>
<td>54 000</td>
<td>100.2</td>
<td>33.6</td>
</tr>
<tr>
<td>DB Netz AG</td>
<td>33 400</td>
<td>46 000</td>
<td>95.9</td>
<td>92.7</td>
</tr>
<tr>
<td>Trafikverket*</td>
<td>14 000</td>
<td>8 000</td>
<td>13.3</td>
<td>21.8</td>
</tr>
</tbody>
</table>

*: Trafikverket’s assignment differs significantly from that of the other infrastructure managers. Trafikverket is responsible for infrastructure for both road and railbound transportation. Moreover, Trafikverket does not perform design, construction or maintenance of infrastructure in-house.

5.9 Conclusions

This investigation builds on previous work in the current work-package (WP8) published as part of deliverables D8.1 and D8.3 as well as work performed by open-/tender call project partners for which WP8 has acted point of contact. The contribution by the current study is primarily related to WP8 task 8.2 “Skills and qualifications”. The qualitative assessment of the impact of S2R technological innovations on future job profiles contained in D8.1 and D8.3 is complemented by a quantitative investigation on its importance with regard to the future composition of competence and staffing need in the railway sector. In addition, the significance of S2R innovations with respect to skills and job profiles development is accounted for by a consolidation of previous studies performed, or commissioned, by WP8.

Automatic passenger and freight train operation on mainline railways is regarded to be the ultimate goal of S2R innovation program IP2 and IP5, respectively. Experiences and lessons learned from the introduction of automatic train operation (ATO) on metro systems worldwide have been reviewed. Focus was on the impact on human capital. In 2016, approximately 16% of the total metro track length in France carried automatic traffic and ATO was adopted by metro lines at 36 different cities worldwide. ATO has potential to deliver productivity increase through reduced labor costs. On the Paris metro, the reduction in operational costs enabled by the introduction of ATO has been estimated to 30%. This cost cannot be directly translated into a decrease in staffing because of the significant difference in professional roles and job profiles for ATO compared to conventional traffic. Onboard staff on rail vehicles operated automatically are observed to learn more tasks and to perform a more multiskilled role as compared to personnel on conventional vehicles. In addition, salaries for personnel on vehicles in automatic operation are higher compared with those for staff on vehicles in conventional traffic. A comparison between 35 different metro systems worldwide operated both conventionally and automatically showed a largest difference in staffing level (evaluated as the total number of staff working at traffic control centres, at stations, on trains and roaming between stations and trains under peak hour normalised to the number of trains in service and number of stations) of 70%.

The impact of technology development on future resource needs has been studied for the Swedish sector related to railway infrastructure (including infrastructure managers, technology consulting companies and railway contractors). The reason why limiting this part of the study to Sweden was the
availability of data on staffing levels of sufficient detail. In addition, a model for numerical prediction of future competence and resource needs was available. The impact of technology development has been addressed by interviews with selected experts of the sector. Finally, the transferability of observations for the Swedish case to other European countries was discussed in a workshop.

The future development of skills and job profiles was assessed by consolidating work published by previous deliverables and the tender research partner TNO, respectively. The impact of the innovations in a technology demonstrator (TD) on the future development of skills and job profiles, as well as affected job categories, was found dependent on the parent IP. TDs related to IP2 and IP5 primarily affected operational jobs (train drivers, train attendees and train operations managers) by gaps in skills in all knowledge areas (STEM, COMM, SOC and ORG). The change in requirements of communicational (COMM), social (SOC) and organizational (ORG) skills among railway personnel resulting from the developments in IP3 was anticipated to be moderate. S2R solutions proposed as part of IP3 primarily relates to improvements in design, monitoring and tools for maintenance planning of the vehicle–track system. This suggests that IP3 will have a general impact on the current sector, for example through an increase in productivity, rather than affecting specific professional roles. A similar expectation was expressed in the interviews with respondents at Trafikverket and the railway contractors in Sweden.

The introduction of S2R innovations will primarily impact professional roles that require railway specific competence. Further, persons having the same professional role but holding different positions in an organisation (i.e. different job profiles), may be affected differently. This means that the evaluation of the impact of S2R technological innovations on future competence and resource needs requires knowledge on job profiles in addition to detailed data on employment levels. In the current study professional roles believed to become significantly influenced by the S2R innovations are: operational jobs (e.g. train driver, rail maintenance technician, operations manager, etc.) and engineering jobs (e.g. mechanical and electrical engineer). Managerial jobs (e.g. team and project leaders, coordinators, etc.) include a larger portion of generic skills and are believed to be less influenced by technology development. The data on employment levels in the Swedish railway sector show that approximately 10 % of personnel at Trafikverket (including persons working with infrastructure for both rail and road transport) are employed in professional roles that require specific competence related to the railway infrastructure. Within this group, the single professional role with the largest number of employees is project leaders belonging to the managerial job category.

The requirements on STEM-skills (Science, Technology, Engineering and Mathematics) were predicted to increase for all IPs and occupational categories. Interviews with experts at Trafikverket partly confirmed this result for occupational category engineers and S2R innovations related to IP3. However, the prediction only applied for personnel employed at specific units of Trafikverket corresponding to approximately 19 % of their staff with railway specific competence. Moreover, together with the introduction of new technology, the establishment of new professions such as e.g. data strategists, data stewards and data engineers are foreseen.

New technology developed by S2R may lead to a short-term increase in competence and resource need. The introduction of the signalling safety system ERTMS, as an intermediate step towards implementation of ATO, serves as an example. Predictions of future resource need related to Swedish railways indicate a significant increase in demand for e.g. signalling planners and signalling technicians driven by investments in ERTMS. Similar observations have been reported for the railways in the Netherlands. In the workshop the representative from DB Netz AG described a similar case in Germany related to the introduction of digital interlocking systems. This emphasises the importance for
quantitative analyses to take into account other significant variables than technological development such as e.g. investments.

Railways represent a mixture of technologies from different eras and hence a specific technology will not be implemented consistently on a complete mainland railway system. New technology will be introduced gradually and not by a sudden revolutionary upgrade. This comment has been received in the interviews with representatives from the Swedish railway sector as well as during the workshop discussions. Trafikverket’s strategy for cost-effective long-term maintenance allows the track design (and adopted technology maturity level) to vary between different lines and locations. Related to this do also the requirements on the railway contractors with regard to inspection intervals, quality of work and extent in performed measures vary. This means that the type of technology and its degree of development varies throughout the track infrastructure by intention of the infrastructure manager. Related to this, the general difficulty of the railway sector to attract and retain talent have been mentioned. Potentially this development may lead to a situation where it becomes more difficult to maintain competence in outmoded technology than to attract personnel with knowledge in new technologies such as for example big data analytics and AI.
6 Conclusions

This document synthesizes the work carried out in WP8 for tasks 8.2 "skills and qualifications" and 8.3 "agile organizations". The main conclusions are respectively drawn in sections 5.9 and 4.5.

In both studies, a bottom-up approach was adopted, leading to a precise view on a limited scope, and allowing quantitative analyses to be carried out where useful. However, this approach inherently lacks conclusions regarding the global railway sector: the key points identified shall then be confirmed and applied at a wider scope to build the global picture.

Limits of the studies and recommendations to be addressed in future research based on lessons learnt are proposed hereafter.

Limit and recommendations for "agile railway organizations"

Although focusing on the professional group point of view of the workers of a crisis management team, an appropriate next step would be to investigate the decision-makers’ point of view. It would be interesting to ask them about the organizational strategy pursued in the creation and management of crisis management teams. To what extent do these teams effectively make the organization more agile from the point of view of decision-makers (regardless of the sense of agility or lack of agility experienced by the members of these crisis management teams)? Another limitation of this study is the comparison between the different agility models existing in SNCF. This comparison is partly based on a systematic study based on scientifically collected data (for the professional group model) and partly on feedback from company practitioners (from different backgrounds) during an informal exchange group (for the expert network model). This second stage aimed above all to put our results into perspective and was therefore not subject to the same methodological equipment as the first. To better investigate the relative advantages and disadvantages of each of these agility models, a dedicated study at a more macro-organizational level would be useful.

Limit and recommendations for "skills and qualifications"

- The current study emphasises the importance of quantitative assessments on the future development of the railway labor market to be based on detailed data on current staff numbers and related work profiles. Technological innovations will primarily impact persons in professional roles that require railway specific knowledge. For the case of Trafikverket and if only personnel that work with rail infrastructure is taken into account (i.e. excluding traffic management staff), these persons make up approximately 10 % of the total number of employees. Furthermore, technological innovations may impact persons with the same professional role (e.g. maintenance engineers) but different job profiles (e.g. different employers or organizational location) differently.

- The detailed quantitative investigation of the current study has been limited to the part of the railway sector related to rail infrastructure in Sweden. It is recommended for future work to extend this study to also account for operators and traffic management. Fully implemented, the impact of ATO on rail traffic operation will be significant. In this regard, it is important for future investigations to take advantage of the experience from metro systems worldwide where ATO already is implemented. A research method similar to that in the current study is proposed with a case study to limit the scope and enable to collect employment data with sufficient detail.

- The introduction of S2R innovations on the mainland railway networks in Europe will be accompanied by significant investments distributed over long time. In this regard, the current work has emphasised the effort related to the adoption of ERTMS and digital interlocking...
systems. It is recommended for future work to survey the long-term investment strategies of selected infrastructure managers in Europe. In addition to providing important information about the short-term increase in resource needs related to the introduction of new technology, this will also provide basis to predict its future impact.
7 References


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8  Annexes

8.1  Annex A - invitation abstract of the workshop

Workshop on future skills and competences
Imagine future based on the Swedish case

A workshop is held to discuss the impact of technological development on the future competence need in the railway sector. Focus is on actors related to the infrastructure including infrastructure managers, technology consulting companies and railway contractors. Below is a brief description of the current research work and the planned content of the workshop.

Background
The Swedish National Road and Transport Research Institute (VTI) is engaged in IMPACT2 as a linked-third body partner to Trafikverket. IMPACT2 is carried out on the initiative of the European joint undertaking Shift2Rail. The current work belongs to WP8 entitled “Human capital” and is performed in collaboration between VTI and SNCF. The impact of technological development on the future competence needs is examined on the basis of an existing and detailed data set describing the composition of personnel related to the railbound infrastructure in Sweden today. Results obtained with a model for prediction of future competence and resource needs have been compiled and used as a starting point for interviews with selected experts at Trafikverket as well as at railway contractors in Sweden.

Workshop
The workshop is arranged to discuss the extent to which results and observations from the Swedish railway sector are useful for the situation in other European countries. VTI presents the work done in the current project. The organisation of the Swedish railway sector is briefly described together with a presentation of how personnel is distributed among its actors and on professional roles. The future development of this personnel is then forecasted based on the infrastructure managers’ long-term budget planning. Interviews have been held with selected experts at Trafikverket and railway contractors. These interviews went beyond questions only focusing on competence needs. During the workshop answers from the interviews are reported and attendees are invited to comment on similarities/differences compared to the situation in their country, or to add additional aspects. Below the questions for the workshop is presented.

Questions for the workshop

- What do you think will be the main challenges for your business during the 10 years ahead?
- In a historical perspective, what impact has technological development had on your business during the past 10-year period?
- How do you think that technological development will affect your business during the coming 10-year period?
- What determines the extent to which your company choose to introduce new technology in your business?
- How do you think that technological development will affect the composition of competence among your personnel during the coming 10-years period?
- Following up on the previous question, which are the associated challenges?
8.2 Annex B - Agenda of the Workshop

Workshop on future skills and competences
Imagine future based on the Swedish case
Mars 11th 2021

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**Agenda**

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<tr>
<th>Time</th>
<th>Content</th>
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<td>09.30 – 09.35</td>
<td>Introduction</td>
<td>F. Letourneaux, SNCF</td>
</tr>
<tr>
<td>09.35 – 09.50</td>
<td>Employment and skills in the EU rail sector</td>
<td>S. Dhondt, TNO</td>
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<td>09.50 – 10.05</td>
<td>Advanced approaches and practices for rail training and education in railways</td>
<td>R. Hadeed, Aston</td>
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<td>10.05 – 10.20</td>
<td>Future resource and competence needs – the Swedish case</td>
<td>P. Torstensson, VTI</td>
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<td>10.20 – 10.30</td>
<td>Rail transportation in France</td>
<td>B. Grau, SNCF</td>
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<td>10.30 – 10.40</td>
<td>Rail transportation in Germany</td>
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<td>10.40 – 10.50</td>
<td>Questions to presenters</td>
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<td>10.50 – 10.55</td>
<td>Break</td>
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<td>10.55 – 11.50</td>
<td>Discussion on future skills and competences</td>
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<td>11.50 – 12.00</td>
<td>Concluding remarks</td>
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9 Antitrust Statement

While some activities among competitors are both legal and beneficial to the industry, group activities of competitors are inherently suspect under the antitrust/competition laws of the countries in which our companies do business.

Agreements between or among competitors need not be formal to raise questions under antitrust laws. They may include any kind of understanding, formal or informal, secretive or public, under which each of the participants can reasonably expect that another will follow a particular course of action or conduct. Each of the participants in this initiative is responsible for seeing that topics which may give an appearance of an agreement that would violate the antitrust laws are not discussed. It is the responsibility of each participant in the first instance to avoid raising improper subjects for discussion, notably such as those identified below.

It is the sole purpose of any meeting of this initiative to provide a forum for expression of various points of view on topics

- (i) that are strictly related to the purpose or the execution of the initiative,
- (ii) that need to be discussed among the participants of the initiative,
- (iii) that are duly mentioned in the agenda of this meeting and
- (iv) that are extensively described in the minutes of the meeting.

Participants are strongly encouraged to adhere to the agenda. Under no circumstances shall this meeting be used as a means for competing companies to reach any understanding, expressed or implied, which restricts or tends to restrict competition, or in any way impairs or tends to impair the ability of members to exercise independent business judgment regarding matters affecting competition.

As a general rule, participants may not exchange any information about any business secret of their respective companies. In particular, participants must avoid any agreement or exchange of information on topics on the following non-exhaustive list:

1. Prices, including calculation methodologies, surcharges, fees, rebates, conditions, freight rates, marketing terms, and pricing policies in general;
2. any kind of market allocation, such as the allocation of territories, routes, product markets, customers, suppliers, and tenders;
3. production planning; marketing or investment plans; capacities; levels of production or sales; customer base; customer relationships; margins; costs in general; product development; specific R&D projects;
4. standards setting (when its purpose is to limit the availability and selection of products, limit competition, restrict entry into an industry, inhibit innovation or inhibit the ability of competitors to compete);
5. codes of ethics administered in a way that could inhibit or restrict competition;
6. group boycotts;
7. validity of patents;
8. ongoing litigations.