Managerial challenges in implementing ERTMS, Remote Train Control and Automatic Train Operation: A Literature review.

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Abstract

This paper explores the management of digitalization projects within the railway industry. It aims to increase and understand the opportunities presented by digitalization and automation in rail operations. Employing a scoping review methodology, the research investigates the execution of European Train Management System (ERTMS), Remote Train Control (RTC) projects, Automatic Train Operation (ATO) spanning from 2005 to 2023, with a particular emphasis on metro automation, remote control of freight and passenger trains, fully automated trains, and highly assisted driving. The refined selection process yielded 30 papers. The analysis of the retrieved papers identified managerial issues, with stakeholder management, change management, and organizational management emerging as recurring themes. Despite the increasing trend in publications, the limited representation managerial issues in ERTMS, RTC and ATO projects in scientific research persists, with implications for the industry's advancement. This research sheds light on the critical intersection of change management and digitalization within the railway industry by showing the impact of ERTMS, RTC and ATO on organizational and scope dynamics. The need for human-centered systems has been highlighted, showing the necessity of involving every echelon of the organization in change management process. Findings provide insights for practitioners, researchers, and policymakers, emphasizing the need of understanding and addressing managerial aspects for successful and sustainable digitalization implementations.

Keywords: Automatic Train Operation; Remote Train Control; ERTMS; Managerial Challenges

1. Introduction

This paper studies the managerial challenges related to the introduction of European Train Management System (ERTMS), Remote Train Control (RTC) and Automatic Train Operation (ATO) within the railway sector.

Recent developments in the railway industry exemplify the growing trend of organizations addressing contemporary business challenges through digitalization and innovative managerial approaches (Singh et al., 2021; Marnewick and Marnewick, 2021; Pan and Zhang, 2021; Ngereja and Hussein, 2021; Papadonikolaki et al., 2019). Moreover, railways operate within an integrated technical and service ecosystem, functioning as sociotechnical systems and networks (Ramtahalsing, 2023; Jablonski and Jablonski, 2019). This sociotechnical nature enables collaborative exploration and enhancement of value-creation processes within the sector, emphasizing the interplay between individual jobs, organizations, networks, and ecosystems (Mohr and van Amelsoort, 2016). This interplay creates pressure on the sector to adapt and transform its operational paradigms to meet the escalating demands for sustainability, efficiency, reliability, and safety, while digitalization is expected to help tackling these issues (Jablonski and Jablonski, 2019). Yet, a successful execution of transformation and digitalization processes in a sociotechnical system requires updated managerial practices (Bednar and Welch, 2020).

For instance, the emergence of technologies like the European Train Management System (ERTMS), Remote Train Control (RTC) and Automatic Train Operation (ATO), aims to advance automation in railways and leverage digitalization to enhance train services (Europe's Rail, 2023). Nonetheless, capturing the anticipated benefits of these technologies entails addressing various organizational and managerial challenges, (Gebauer and Pree, 2008; Karvonen et al., 2011; Powell et al., 2016; Wang et al., 2016; Pattison et al., 2020; Gadmer et al., 2022). While industry white papers have addressed these challenges (TNO, 2018; Jernbanedirektoratet, 2023, WSP 2023), academic research on the managerial aspects of introducing ERTMS, RTC or ATO is largely lacking. Appropriate managerial practices are crucial for supporting successful execution of digitalization ventures and open innovation projects (Badewi, 2022). Therefore, this paper aims to explore ERTMS, RTC and ATO managerial challenges. The study is related to the flagship project FP2 R2DATO under the Europe's Rail Joint Undertaking.

This exploration adopts an organizational perspective, since transport projects are known to engage multitude and diverse stakeholders (Locatelli, Invernizzi and Brookes, 2017), bring major public attention (Ambrosino et al., 2015), and entail high investment cost (Flyvbjerg, 2006). Adopting this perspective thus allows to conceptualize and analyze the integration of these characteristics across the hierarchical structure or network of railway organizations (Müller et al., 2019; Drouin et al., 2017; Turner and Müller, 2003). ERTMS, RTC and ATO projects are consequently considered within the broader scope and context of their parent organizations, i.e. railway organizations (Müller et al., 2019; Turner and Müller, 2003). This theoretical standpoint aligns with the sociotechnical nature of digitalization in railways, emphasizing the importance of aligning technical systems with social systems at all organizational levels (Ramtahalsing, 2023; Badewi, 2022; Grant et al., 2013). To achieve this alignment, a scoping review methodology is employed, following guidelines provided by Besinovic (2020) and Van Wee and Banister (2015) for the railway sector and by Klein and Müller (2020), as well as Zerjav et al. (2023), for the managerial domain. The recommendations for such reviews in the domains of railways and management are similar and this study is aligned with both. The subsequent sections of the paper provide an overview of the concepts used, detail the methodological approach, present the results, and discuss their implications, concluding the paper.

2. Conceptual overview

In the following section, the conceptual background of this paper will be outlined, starting with an overview of the literature on management and digitalization, and followed by project management and digitalization within the rail sector. The section is completed with an overview of ERTMS, RTC and ATO.

2.1 Managing digitalization

Implementing digitalization necessitates change and change management has two main perspectives: organizational change management and managing scope changes. Organizational change management involves navigating unique project-induced changes within organizations, often driven by project promoters' desires and project objectives (Levin & Klev, 2016). This type of change management is typically focused on the use of a project delivery, such as new infrastructure of new technologies. In other words, how a project delivery is used to generate the intended value. Conversely, managing scope changes focuses on managing, and often aiming to minimize, changes to project parameters (Kerzner, 2022). This type of change management typically relates to the project execution and what the project shall deliver (Olsson, 2018).

Digitalization has increasingly intersected with organizational management, driven by the imperative to enhance predictability and efficiency amid technological advancements and disruptive effects on business processes (Yordanoza, 2022; Pan & Zhang, 2021). Effective organizational management is crucial for successful digital transformation, necessitating a long-term vision and comprehensive understanding of organizational needs (Lafioune et al., 2023). Modern business operations have triggered the adoption of digital solutions, prompting updated managerial practices at all organizational levels (Zhong et al., 2023). However, digitalization and automation introduce cultural transformations within organizations, impacting stakeholders and necessitating robust, adaptable, and accessible organizational management strategies (Zhang & Guo, 2022).

Implementing such strategies entails multifaceted initiatives engaging various organizational levels (Zimmer, 2019; Brady & Davies, 2016), which creates a shift towards a bottom-up team leadership that necessitates ongoing change management efforts to accommodate evolving stakeholder expectations (Marnewick & Marnewick, 2020). Stakeholder management is thus intricately linked to change management, requiring continuous adaptation of project strategies to meet evolving stakeholder needs amid digital transformations (Morris, 2013; Whyte et al., 2016), and provides a link between organizational change management and scope change management. Indeed, digitalization projects induce organizational changes at both human and structural levels, necessitating expertise, awareness training, and organizational restructuring to fully leverage digital capacities (Melberg & Gressgåard, 2023). Mitigating secondary changes and understanding the transformative potential of digitalization projects are critical for successful organizational outcomes (Pádár et al., 2017).

These challenges underscore the importance of examining disruptive technologies from an organizational management standpoint (Pan & Zhang, 2021), but existing research on digitalization predominantly focuses on specific digital tools, such as Building Information Modeling and social media applications (Toukala et al., 2023). There is thus a notable gap in understanding the utilization and implications of technologies like ERTMS, RTC and ATO within the railway industry from an organizational perspective. Next subsection will present the changes and challenges brought upon by infrastructure projects and digitalization projects in the transport sector.

2.2 Project management and digitalization in the transport sector

Transport Infrastructure Projects (TIPs) are typically stretch across decades with budgets ranging from millions to billions of dollars, all while grappling with considerable uncertainties and risks, which in turn makes time and costs forecasts often inaccurate (Bruzelius et al., 2002; Flyvberg, 2006; Locatelli, Invernizzi and Brookes, 2017). Even though the hardware components are most visible in TIPs, they may also contain significant elements of digitalization. In the case of rail infrastructure, they are characterized by complexity, as they undergo a life cycle from conception through design, construction, operation, and maintenance to its end. Multiple actors, such as designers, construction companies, operators, and maintenance firms, are involved, making effective information exchange critical (Pasetto et Giacomello, 2023). This can be facilitated by adopting effective project management practices and practices. Locatelli, Invernizzi and Brookes (2017) analyzed 30 TIPs and showed that when proactive measures such as public engagement initiatives are taken to mitigate dissatisfaction and opposition, projects tend to progress smoothly and meet their deadlines.

Based on their study, Sözüer and Spang (2014) demonstrated that, in TIPs, stakeholder and change management are among the least used practices the organizations. They recommend early identification and analysis of stakeholders in the planning phase. Managing stakeholders from the outset will aid in coordinating issues, which can prevent conflicts later (Olander and Landin, 2005). This proactive approach also enhances public acceptance of the project and potentially reduces the planning duration, especially the approval phase (Sözüer and Spang; 2014). Regarding change management processes, organizations should address and prepare changes stemming from unclear task definitions, regulatory shifts, evolving political opinions, and alterations post-approval. Clearly defining tasks and objectives early in the planning phase, especially during preparation, is crucial to minimize changes in specifications and scope (Sözüer and Spang; 2014).

Locatelli, Invernizzi and Brookes (2017) demonstrated that the introduction of a new technology in a TIP is linked to poor performance and delays in the planning phase. They showed that such technologies require more front-end management, which can delay the start of the planning phase. Such delays can also pose a threat to approval, especially if stakeholders are unfamiliar with the technology (Locatelli, Invernizzi and Brookes, 2017). Moreover, Ambrosino et al. (2012) showed that the introduction of intelligent transport systems is hindered by many aspects. They concluded that there is an inability to tailor technological solutions that match the real operational needs, a tendency to overlook critical interaction challenges with the technology's supplier, and a business approach that doesn't consider the supplier as collaborative partners, but rather as a provider. The deployment of such technologies is also slowed by unclear system requirements, limited understanding of comparable challenges, a procurement emphasis on technology rather than needs, and contracts not aligned with performance and support processes (Ambrosino et al., 2012).

In addition, when such technological project is undertaken in the railways, it is prone to be delayed in the construction phase (Locatelli, Invernizzi and Brookes, 2017). It is claimed that the sector has yet to catch up in adopting cutting-edge methods and technologies as compared to other transport fields. This delay is partially attributed to the requisite expertise and readiness of personnel, since managerial considerations have emerged as key obstacle to the progression and implementation of Industry 4.0 technologies in the railway industry (Dolinayova et al., 2015; Bubnova, et al., 2018; Gerhátová et al., 2021). Yet, digitalization stands as an important objective within the railway sector, shaping its future trajectory (Tsvetkov, Shaytura, and Ordov 2019). The sector's pivotal challenge lies in delivering efficient and appealing transportation projects to customers while capitalizing on the transformative potential of digital advancements (Tsvetkov and Shaytura, 2019).

This was noted by Geyer and Davies (2000) who asserted that technological advancement within railway networks is intricately tied to the implementation of expansive, capital-intensive endeavors. These projects require collaboration and coordination among numerous organizations interconnected within an innovation network (Rizopoulos et al., 2021). Consequently, project-based organizations, such as the technology supplier, and the rail operator are intertwined, which illustrates a tendency to share technical and organizational components (Geyer and Davies, 2000). This means that project-based activities are regarded as essential parts of new technology implementation in the railways, since they are crucial for sustaining system efficiency, resolving significant obstacles hindering network expansion, and enabling system adaptation to emerging regulatory or market demands (Gayer and Davies, 2000).

In brief, stakeholders and components of the railways need to collaborate effectively to deliver safe services and maintain the desired level of performance (Nemtanu and Marinov, 2018). However, project-based activities, such as the implementation of ERTMS, RTC and ATO, have a significant influence this collaboration, making it imperative to examine and understand their managerial impact for successful implementation, an endeavor that will be complete in the next subsections.

2.3 European Rail Traffic Management System

The European Rail Traffic Management System (ERTMS) aims at unifying the diverse national train control and command systems in Europe to enhance rail transport safety, capacity and efficiency (Schuitemaker and Rajabalinejad, 2017). It thus aims at assuring the interoperability of rail transport within Europe, since the standardization of rail signal control systems facilitates the transport of goods and passenger within the continent (Kochan et al, 2023). ERTMS is designed with various levels of specification tailored to different operational needs. Depending on how it's implemented, ERTMS can bring forth a range of advantages such as cab signaling, automatic train protection, and the potential for future advancements like moving block train separation (Thomas et al., 2008). These features enhance the safety and efficiency of rail operations and pave the way for technological advancements and increased capacity in the rail network.

The establishment of this technology comes with novel managerial challenges and impediments that must be addressed to capture the full benefits of (Abbas et al, 2022; Krmac and Djordjevic, 2018).

2.4 Remote Train Control

RTC is recognized as an essential technological foundation necessary for the implementation of ATO systems (Masson et al., 2019). RTC enables a remote operator to assume control and oversight of rolling stock, engage with other remote agents and entities (whether technical or human), and ensure complete safety, even when confronted with operator-related faults, environmental challenges, or technical system malfunctions (Masson et al., 2019). Remote driving finds application in situations where assuming remote control over an automatic train becomes imperative, particularly following a malfunction in the ATO components (Tonk et al., 2021). In such scenarios, achieving RTC capability becomes a primary objective to be attained before the full deployment of ATO on mainlines can be considered safe and viable (Tonk et al., 2021). According to Alsaba et al. (2020), there are currently three main applications for RTC: (1) the coordination of activities encompassing the segments between the yard and the client's site, with the aim of minimizing extended transportation periods and driver waiting times; (2) the administration of technical routes connecting maintenance centers and stations, ensuring the efficient functioning of this infrastructure; (3) the retrieval and recuperation procedures associated with automatic trains, whether they are experiencing failures or not.

RTC can enhance operational resilience by remotely overseeing, controlling, and intervening in cases of disruptions, but the realization of this necessitates the development of innovative operational strategies, as highlighted by Gadmer et al. (2022). Upon introducing RTC, organizations must establish clear protocols dictating the time and manner in which decision-making authority regarding train control transitions from one entity to another. This transition process follows an incremental trajectory, involving extensive deliberations that engage a broad range of stakeholders (Gadmer et al., 2022). For instance, scenarios in which a driver may need to engage in physical tasks during unforeseen events, such as evacuations. In such cases, the driver's responsibilities extend to collaborating with traffic control, as he/she needs to formulate the most effective approach and effectively communicating it to passengers (Jansson, Olsson, and Fröidh, 2023).

2.5 Automatic Train Operation

ATO serves as a comprehensive framework, since there are four different stages of automation, referred to as Grades of Automation (GoA) in the international standard IEC 62290-1 (IEC, 2014). In GoA1, the train driver manually operates the train, potentially with the assistance of driving advisory systems. In GoA2, acceleration, deceleration, and stopping are automated. The train driver retains responsibility, actively monitors the ATO system, and steps in when necessary. In GoA3, the ATO systems operates the train independently, allowing the train driver to be outside the cab and engage in other tasks. In GoA4, the ATO system operates the train autonomously and intervenes in the event of potential incidents. No train driver is onboard, and disruptions are managed remotely or by a maintenance team (IEC, 2014). The global automatic train market grew from $9.08 billion in 2022 to 9.79 billion in 2023 (Business

Research Company, 2023), while automated metros are expected to reach 2200km globally by 2025 (Briginshaw, 2016).

The potential benefits of utilizing ATO technology are numerous (Singh et al., 2021). Notably, it is expected to contribute to a decrease in accidents and an overall improvement in safety. Railway companies can anticipate a reduction in operational costs with the deployment of automatic trains. A decrease in emissions produced is envisaged, while the capacity for passengers will be expended, thus contributing to environmental and transport sustainability. With these outcomes, railway services are anticipated to become more sustainable, reliable, robust, and efficient (Singh et al., 2021; Allied Market Research, 2020).

However, it must be noted that the deployment of ATO is mostly confined within metro lines (around 40 cities in the world have automated rail lines) and the usage of such technologies on mainline railways is quite limited (Shing et al., 2021). Indeed, attaining the desired levels of autonomy in train systems is met with several challenges. For instance, Wang et al. (2016) conducted a comprehensive survey focusing on driverless train operations within urban transit rail systems. Their investigation revealed multifaceted challenges, encompassing safety concerns, train technology intricacies, and communication issues. The successful realization of automated train systems thus hinges on the active involvement and collaboration of a diverse array of stakeholders, including manufacturers, fleet operators, infrastructure developers, labor unions, citizen organizations, and government officials. Their collective engagement and cooperation are indispensable for the effective implementation and operation of ATO systems. To respond to these challenges, organizations are undergoing structural and cultural transformation to integrate this new technology, thereby giving rise to organizational and managerial complexities (Singh et al., 2021).

3. Research gap

The previous conceptual overview allowed the identification of a research gap that will be uncovered in the following section.

In the first subsection of the conceptual overview, it was shown that effective change management encompasses organizational change management and managing scope changes, which are essential for successful digital transformation and requires comprehensive strategies to address evolving stakeholder needs and mitigate the transformative impact of digitalization on organizational structures and processes. Then, it was demonstrated that TIPs, especially in rail infrastructure, span decades, and face significant uncertainty, but effective project management practices and processes can mitigate delays and foster public acceptance. In light of this, digitalization remains a key objective in the railway sector, yet its implementation is slowed by managerial considerations and organizational readiness, therefore highlighting the importance of collaboration among various stakeholders for successful technology integration and system efficiency in railway networks. Next, ERTMS, RTC and ATO were presented as examples of digitalization projects within the rail sector, while their respective implementation faces challenges that requires collaboration among stakeholders and organizational transformation.

There is thus a gap in the detailed exploration into the specific managerial challenges associated with the implementation of ERTMS, RTC, and ATO in the railways. While some literature acknowledges the importance of using established managerial practices for digitalization venture in the transport sector, it does not delve into the factors that may hinder the successful adoption of these aforementioned technologies, which justify the dual research question of this paper: **What are the managerial challenges associated with the deployment of ERTMS, RTC and ATO addressed in previous studies, and how can these challenges be discussed in both an organizational change and a scope change management perspective?**

As these challenges are integrated and analyzed in an organizational perspective, it is important to situate them in the broader context of the projects in which they take place, which is illustrated in Figure 1, that shows how project attributes evolve during different project phases (Mikkelsen & Riis 2003; Kerzner, 2022).

It is well established in project management literature to use illustrations like Figure 1 to indicate how project attributes change during different project phases. Even though the detailed shapes of the curves vary between different authors and models, they share the underlaying logic. This figure summarises two groups of curves, with a time of the project on the x-axis, and a general low to high scale on the y axis. One curve begins high in the front-end and move to low as the project progresses. Uncertainty, significance of decisions and the degree of freedom to manoeuvre typically show this development, being high at the beginning of the project, and low at the end. The other curve begins low and end up high towards the end of the project. This includes variables such as the accumulated cost, available information, and cost of scope changes. Even though the actual shapes of the individual curves vary between different variables and studies, they can be clustered in the two general groups.

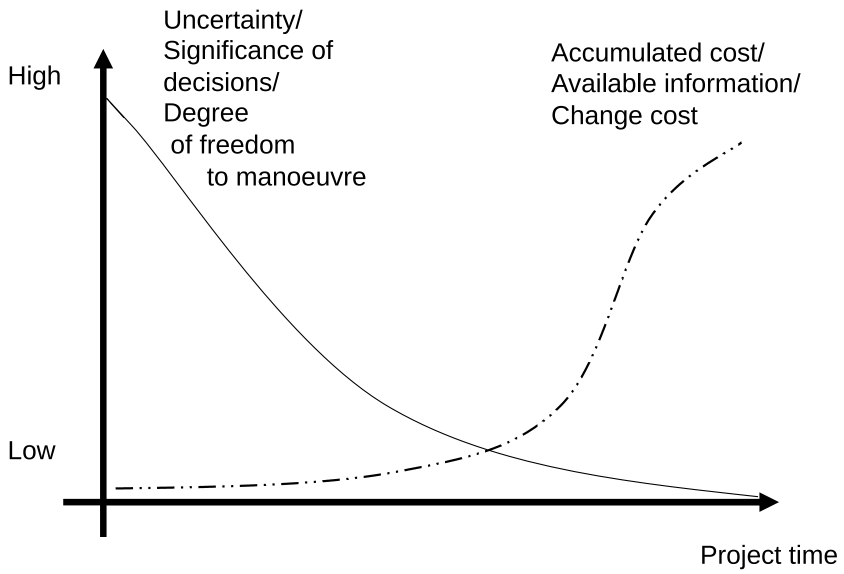

Figure 1 - Development of selected project characteristics in a time perspective. (Based on Christensen and Kreiner 1991; Mikkelsen and Riis 2003; Olsson, 2015).

Next section will outline the methodological approach used to answer this question.

4. Methodology

A scoping review methodology is employed. The primary goal of this review is to examine the execution of ATO, RTC and ERTMS projects in past instances. Our aim is to shed light on the most common managerial challenges and pinpoint any possible hurdles that need to be addressed. The scope of these cases encompasses a range of areas, including metro automation, remote control of both freight and passenger trains, fully automated trains, and highly assisted driving, as documented in the works of Powell et al. (2016), Gadmer et al. (2021), Yusuf et al. (2020), and Trentesaux et al. (2018). To conduct the review effectively, the authors adhered to established guidelines proposed by Van Wee and Banister (2015), Besinovic (2020), Klein and Müller (2020), as well Zerjav and colleagues (2023). Database search was performed in Web of Sciencl and Scopus.

In the first step, keywords were used to initiate the search in the selected databases. The keywords used are presented in Table 1. The scope was restricted to paper in English from 2005 to 2023, including only peer reviewed journal papers. In the second step, titles, keywords and abstracts were checked manually and the selection was refined by removing all papers that were not addressing ATO, ERTMS or RTC. In the third step, the research was refined again by excluding papers that were only addressing specific technical aspect of the rail sector and not assessing the challenges, costs and managerial, organizational, or human aspects. In the fourth and final step, a final refinement was conducted, sorting of all papers based on full texts. The Prisma flow chart of this process, which is inspired by Ruben et al. (2020) methodology, is illustrated in Figure 2. A total of 30 papers were reviewed.

Table 1 - Keywords search in databases

Main Keyword	AND	OR	OR	OR	Web Of Science	Scopus
ATO	Costs	Management	Challenges	Implementation	161	157
Automatic Train Operation	Costs	Management	Challenges	Implementation	193	157
RTC	Costs	Management	Challenges	Implementation	286	259
Remote Train Control	Costs	Management	Challenges	Implementation	108	73
ERTMS	Costs	Management	Challenges	Implementation	27	42

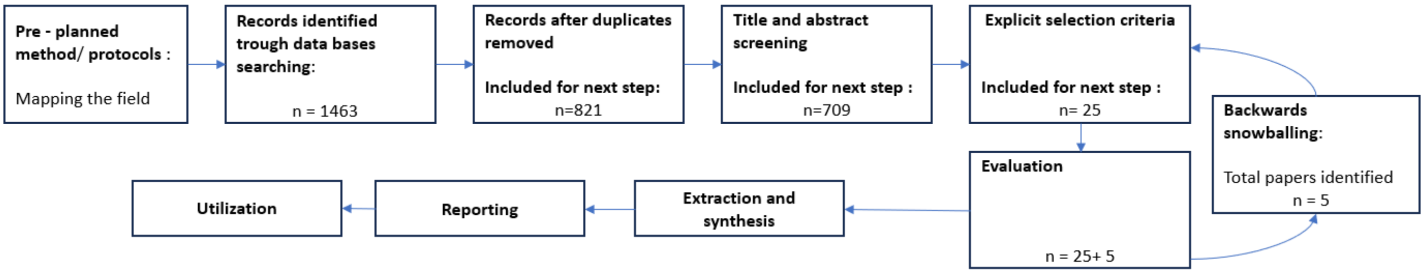

Figure 2- Process of literature review (Ruben et al., 2020).

5. Results

As previously mentioned, the review encompassed 30 papers spanning the years 2005 to 2023. The annual publication rate remained steady until 2022 when a notable surge occurred, with 5 articles published that year and an additional 7 in 2023. This illustrate that managerial issues arising from ERTMS, RTC and ATO deployment are gaining prominence both in industry and academic circles, as illustrated in Figure 3

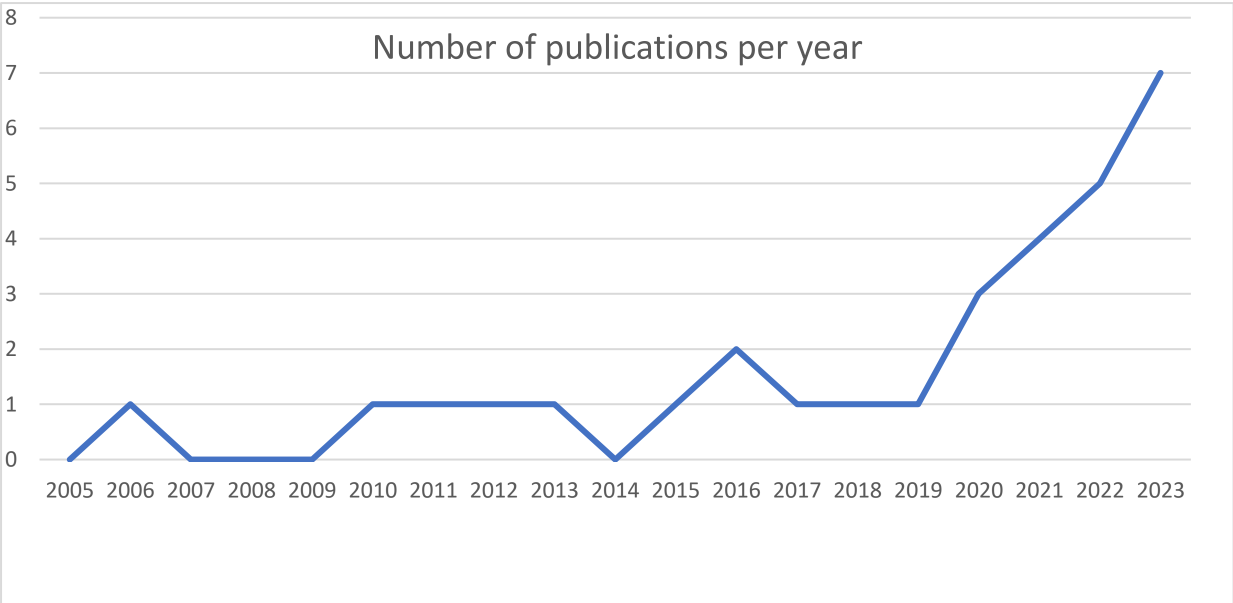

Figure 3 - Distribution of papers per year of publication.

The most frequent publications channels are charted in Figure 4. Journal of Rail Transport Planning & Management stands out as the publication channel with the most publications, with five publications. It's followed by WIT Transaction in the Built Environment, IEEE Access, and Research in Transportation Business and Management with each two publications.

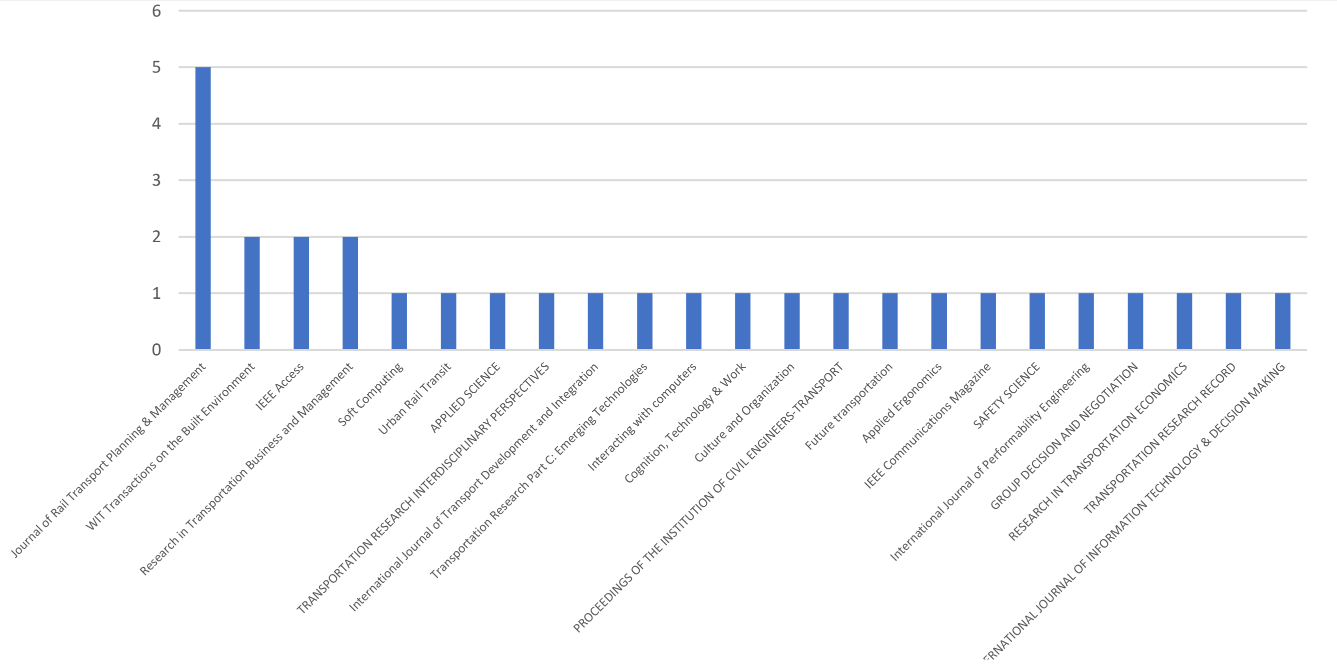

Figure 4 - Distribution of papers per journals

Figure 5 illustrates the distribution of the technology discussed in the publications. On 30 papers, 3 were analyzing RTC, 13 for ERTMS and 12 for ATO. Two papers were studying ERTMS and ATO, bring the total for each at 14 and 15. This shows that research on RTC and its managerial implications are considerably lacking, in comparison with ERTMS and ATO. It also shows that no research has been done on the relationship between the three technologies, or on the relationship between ATO and RTC, and the relationship between RTC and ERTMS.

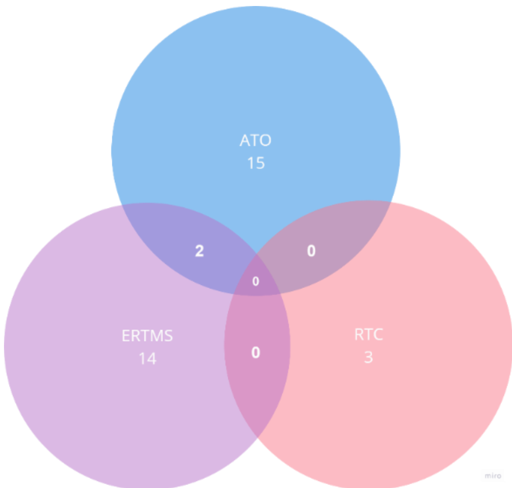

Figure 5 – Distribution of technology per publication

Figure 6 illustrate the different research methods from the retrieved papers. 13 of them utilize a qualitative methodology, while 3 of them utilize a quantitative methodology. 8 of them had a mixed approach (quantitative and qualitative) and 6 of them were conceptual papers.

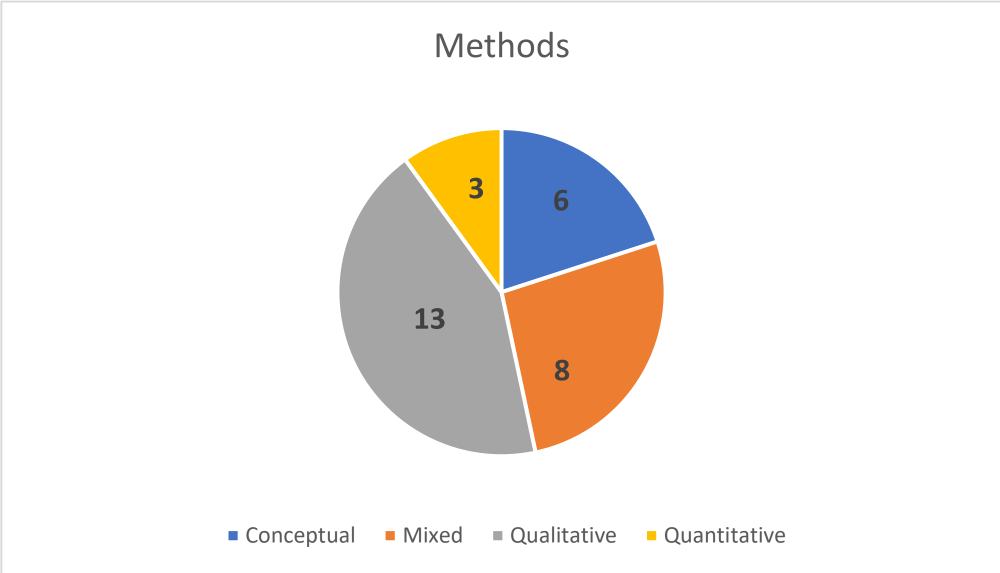

Figure 6 – Used methods in publications

The analysis of the retrieved papers identified various management themes. The most frequent ones were stakeholder management, change management and organizational management; some papers had implications related to all three of these managerial aspects. Stakeholder management was identified 14 times, change management 13 times and organizational management 14 times. These findings, presented in Table 2 set the stage for an examination of the implications in the upcoming sections.

Sources	Stakeholder	Change	Organizational	Others	ERTMS	RTC	ATO
Thomas (2006)		X					X
Patra et al. (2010)				X	X		
Karvonen et al. (2011)	X						X
Smith et al. (2012)	X	X	X		X		
Laroche and Guihéry (2013)				X	X		
Moreno et al. (2015)			X		X		
Forsberg (2016)	X				X		X
Powell et al. (2016)	X	X	X				X
Yin et al. (2017)				X			X
Krmac and Djordjevic (2018)			X		X		
Armstrong and Preston (2019)				X		X	
Pacaux-Lemoine et al. (2020)	X	X	X			X	
Ranjbar and Olsson (2020)		X	X		X		X

Fernandez-Rodriguez et al. (2020)				X			X
Singh et al. (2021)	X	X	X				X
Rosberg et al. (2021)	X	X			X		
Brandenburger et al. (2021)	X						X
Bekius et al. (2021)		X	X		X		
Cogan et al. (2022)	X					X	
van der Weide et al. (2022)	X				X		
Filip (2022)		X					X
Abbas et al. (2022)		X	X		X		
Wang et al. (2022)			X				X
Morast et al. (2023).	X	X					X
Jansson et al. (2023)	X	X	X				X
Djordjevic et al. (2023)			X				X
Olsson et al. (2023)	X				X		
Akse et al. (2023)		X	X		X		
Rosberg and Thorslund (2023)	X				X		
Cort and Lindblom (2023)			X				X
30	14	13	14	5	14	3	15

Table 3 - Distribution of project management themes per paper

6. Discussion

As show in table 3 and table 4, the most reoccurring themes are stakeholder management, change management and organizational management. This highlights the growing managerial challenges faced by railway organizations when engaging in remote or automated functions (Singh et al., 2021). These three managerial themes will thus be explored in the following paragraphs.

6.1 Stakeholder management

A recurring topic within stakeholder management is the question of how to respond to changes in stakeholder responsibilities from engaging with digital, remote, or automated systems, especially train drivers' responsibility. In the case of ERTMS, van der Weide et al. (2022) demonstrated that it takes about one year for a train driver to become proficient with the technology. They further recommended that this would require performing at least 10 to 19 duties per quarter with at least one ERTMS route. After that year, frequency can be readjusted according to driver's needs, but should perform a minimum of 6 duties per quarter with at least one ERTMS route (van der Weide et al., 2022). Also, Forsberg (2016) noted that technological progress, such as ERTMS, creates ambiguity regarding certain areas of responsibility. Such ambiguity thus requires clarified roles for drivers (Forsberg, 2016). Indeed, a systematic literature review by Rosberg et al. (2021) illustrated that the use of ERTMS transpose the visual focus of the driver inside of the cabin, rather than outside, potentially leading to drivers to omit crucial information that necessitates their attention.

Such findings corroborate Pacaux-Lemoine et al. (2022) research on how RTC revolutionizes the railway industry by reshaping collaboration dynamics among stakeholders, as team members now must cooperate with machine agents. The remote operators, disconnected from the train, can't independently gather environmental data and make real-time decisions. Instead, they rely on an advisory system that collects information, performs comprehensive analyses, and generates predictive insights about the driving process. These insights then inform the actions of the remote operator (Pacaux-Lemoine et al. (2022). Likewise, when implementing ATO, neglecting the duties and expertise of drivers could result in negative effects on service quality and pose safety concerns.

Thus, when deploying ATO, it is crucial to establish new strategies to make up for the absence of drivers' observational advantages. These strategies involve comprehensively defining their roles to assert how an automated system can fulfill them (Karvonen et al., 2011). Ranjbar and Olsson (2020) recommend that, to fill the void between human operation and novel technologies, diminish human errors and improve performance within the railways, it is necessary to develop employees' competencies with new technologies. Unions have frequently expressed significant resistance towards the heightened implementation of automation, primarily citing concerns related to the potential ramifications such as job losses and staff relocations (Powell et al., 2016).

Moreover, as noted by Powell et al. (2016), the public acceptance of driverless trains is mixed, and passengers should be informed that they are using an automated system. This is also shown by Morast et. (2023), who demonstrated that GoA3 and GoA4 trains are generally accepted, but certain demographic or socio-economic characteristics can affect an individual perspective on unattended trains. Congan et al. (2022) research revealed that RTC with human operators can foster the acceptance of automated trains. They also noted that driverless operators are supported, but passengers still prefer the presence of onboard personnel.

These findings corroborate studies in digitalization management (Marerwick and Marnewick, 2020; Ngerejra and Hussein, 2021; Brady and Davies, 2016) assertion that the implementation of digital tools will have the most significant impact on project team members, who are key stakeholders in the process. Effectively including team members in the digitalization process will entail major organizational changes, such as a novel bottom-up approach (Marnewick and Marnewick, 2020), the cultivation of a collaborative organizational culture (Ngerejera and Hussein, 2021) and redistribution of resources (Brady and Davies, 2016). Since railways are sociotechnical systems and do not evolve in isolation within their network (Ramtahalsing, 2023; Jablonski and Jablonski, 2019), the deployment of ATO and RTC impacts a broad range of external stakeholders, such as passengers and unions.

However, some key issues regarding stakeholder management were not found in the retrieved literature. For instance, in the case of RTC and ATO, there was no mention on the business relationship that is maintained by the operator with the supplier of the technology. This confirms Ambrosino et al. (2012) findings that, in the railway industry, challenges and interactions with the technology suppliers are often overlooked, leading to suboptimal outcomes. Also, as noted by Gayer and Davies (2000), digital ventures in the railways requires interconnectedness between the involved organizations, thus exemplifying the sociotechnical nature of the sector. Finally, the findings expose that most of the studies on the impacts of deploying ERTMS, RTC or ATO are focused on the train drivers. While pertinent, not considering the impacts on managerial personnel and other internal stakeholders perpetuates Gerhátová et al. (2021) assertion that managerial issues are a major impediment to deploying and harnessing the benefits of novel technologies in the railways, which also shows that stakeholder management could be improved (Sözüer and Spang, 2014).

6.2 Change and organizational management

Papers studying the implementation of ERTMS present numerous factors impacting change and organizational management in railway companies. Notably, Smith et al. (2012) mentioned that failing to properly define the specificities can produce changes during the development and validation of such projects. They thus suggest that member states should, at an organizational level, foster a culture that enhance collaborative efforts between them and prioritize similar safety considerations (Smith et al., 2012). Similarly, Abbas et al. (2022) found that the deployment of ERTMS was slowed by the diverse business models of the organizations and the organizational tendency to favor their own safety approaches. A collaborative culture is consequently needed, coupled with raising awareness on the effects of system changes produced by the introduction of ERTMS. However, technical aspects, rather than organizational, are the focus such projects (Abbas et al., 2022). This is also highlighted in Asket et al. (2023) study that demonstrated that uncertainty and changes in ERTMS projects were caused by behaviors from certain stakeholders and not from technical features.

Moreover, deploying and operating ATO requires involving every echelon of the organization in the change management process (Thomas, 2006). It ensures that all the required factors are assessed when converting to an automated system, which includes: the operational and services benefits expected from the technology, the safety and risks mitigation strategy, the acceptance of the system by the relevant stakeholders, and the integration and migration of the old system into the new system (Thomas, 2006). This is show in Jansson et al. (2023) study, where they present six categories, in which the drivers play a role, that automated systems must be able to undertake: Detect, Report, Inspect, Adjust, Manage passengers and Responds to train orders. Indeed, attaining the desired autonomy by switching the imputably of these roles to an ATO system requires the participation of every organizational echelon, as it changes the operational paradigms of the railways (Shi et al., 2021).

Such studies show the need for updated organizational strategies when setting up ERTMS, RTC or ATO. This supports organizational change management theories who assert that the complete harnessing of the benefits of digitalization is contingent upon the implementation of novel organizational management strategies (Lafioune et al., 2023). Thus, as proposed by such theories (Melberg and Gressgård, 2023; Lafioune et al., 2023; Zhong et al., 2023), railway companies should undertake a comprehensive overhaul of their work processes, organizational structures, and cultures, while developing effective communication strategies to optimally harness the benefits of ERTMS, RTC and ATO (Melberg and Gressgård, 2023; Lafioune et al., 2023; Zhong et al., 2023).

This review can be used to elaborate on both perspectives of change management; organizational change management and scope change management. Building on figure 1, figure 7 illustrate that a key concern in scope change management is to manage the rising of the “Cost of scope change” curve over time in a project. This indicates that late changes in a project are costly, since they can trigger redesign and contract amendments. However, in an organizational change perspective, the project in itself represents the “change” which needs to be managed. This is by definition a major change, and a desired one; the purpose if the project is to introduce something new such as a new piece of transport infrastructure or a new technological system (or, commonly, both). The scope changes only represent adjustments of this big desired change (even though such changes may be costly).

The y-curve in figure 7 can be seen as an illustration of a project generating organizational change, such as introducing ERTMS, RTC or ATO. This study and previous studies have highlighted the importance of utilizing the room for maneuvering in the front-end of projects. However, there are indications that stakeholder acceptance for organizational change may require continuous change to gain acceptance. While it is likely that technical scope and configuration changes of ERTMS, RTC or ATO systems have a scope change cost as indicated in the figure, the authors find that organizational change may not follow that curve. In fact, there are indications that organizational change, and at least change resistance is not a low-to-high type of curve, but rather a high to low, as suggested in figure 7. This highlights the need to be aware of the different characteristics of project change management; organizational change does not follow the common knowledge curve for scope changes.

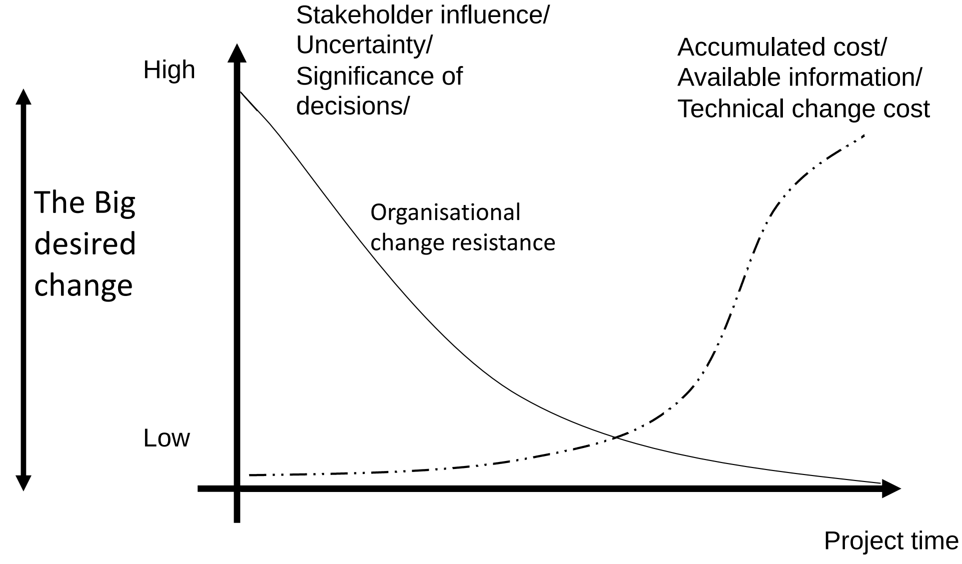

Figure 7 - Revised illustration of the development of selected project characteristics in a time perspective, with special focus on two perspectives on change management.

7. Conclusion

This study as delved into the managerial challenges associated with the deployment of ERTMS, RTC and ATO. Changes in stakeholder roles and responsibilities, coupled with the transformation of organizational and managerial frameworks, present hurdles that demand careful consideration and strategic solutions. Sociotechnical systems, such as railways, demand a collaborative exploration of value-creation processes, with a particular emphasis on aligning technical and social systems across organizational levels (Jablonski and Jablonski, 2019; Müller et al., 2019).

Initiatives like the R2DATO project underscore the potential of ATO and RTC to revolutionize the railway sector (Europe's Rail, 2023). However, realizing these benefits requires addressing numerous organizational and managerial challenges as illuminated by the research findings. The study emphasizes that the effective management of ERTMS, RTC and ATO projects is paramount for successful digitalization in the railway sector. The scoping review methodology adopted aligns with the sociotechnical nature of digitalization in railways. The research question guiding the exploration - What are the managerial challenges associated with the deployment of ERTMS, RTC and ATO are addressed in previous studies, and how can these challenges be discussed in both a change management and scope management perspective? - has enabled the identification of prospective organizational risks and obstacles that may surface during the implementation of these digital technologies.

The results emphasize the need for comprehensive organizational change strategies that address the evolving nature of such projects. Indeed, the findings underscore the importance of stakeholder management, change management, and organizational management in navigating the novel challenges posed by the integration of digital technologies in the railway industry. Moreover, the impact of ERTMS, ATO and RTC on organizational dynamics and the need for human-centered systems have been highlighted, emphasizing the necessity of involving every echelon of the organization in the change management process.

Regarding the second part of the research question (how can the observed challenges be discussed in an organizational and scope change management perspective), figure 7 provides an illustration of nuances and aspects of change management in railway digitalization projects.

Both organizational and scope change management emerge as key success factors for railway digitalization projects.

Future research endeavors should delve into transitioning from project implementation to day-to-day operations. Existing literature focuses on the managerial challenges inherent in the development and deployment phases of ERTMS, ATO, and RTC projects, neglecting the ongoing operational and organizational adaptations required post-implementation. It is indeed imperative to recognize that the introduction of digital technologies initiates profound organizational changes across multiple dimensions (Melbrg and Gressgåard, 2023). On the human dimension, modifications in stakeholders' roles creates demands for expertise, awareness training and communication. On the organizational dimension, firms must reconfigure their work, organizational structures, and cultures to fully leverage the advantages of digitalization (Melberg and Gressgåard, 2023), which entail continuous change management efforts (Morris, 2013; Whyte et al., 2016; Manerwick and Manerwick, 2020). Thus, future research should not only bridge the gap between project and operational phases but also explore the intricate interplay between technological implementation and organizational transformation. By doing so, researchers can provide valuable insights into the holistic implications of digital technology adoption in railway operations and facilitate informed decision-making processes for industry stakeholders. In the transport sector, the transformation process induced by ERTMS, RTC and ATO is illustrated in figure 8.

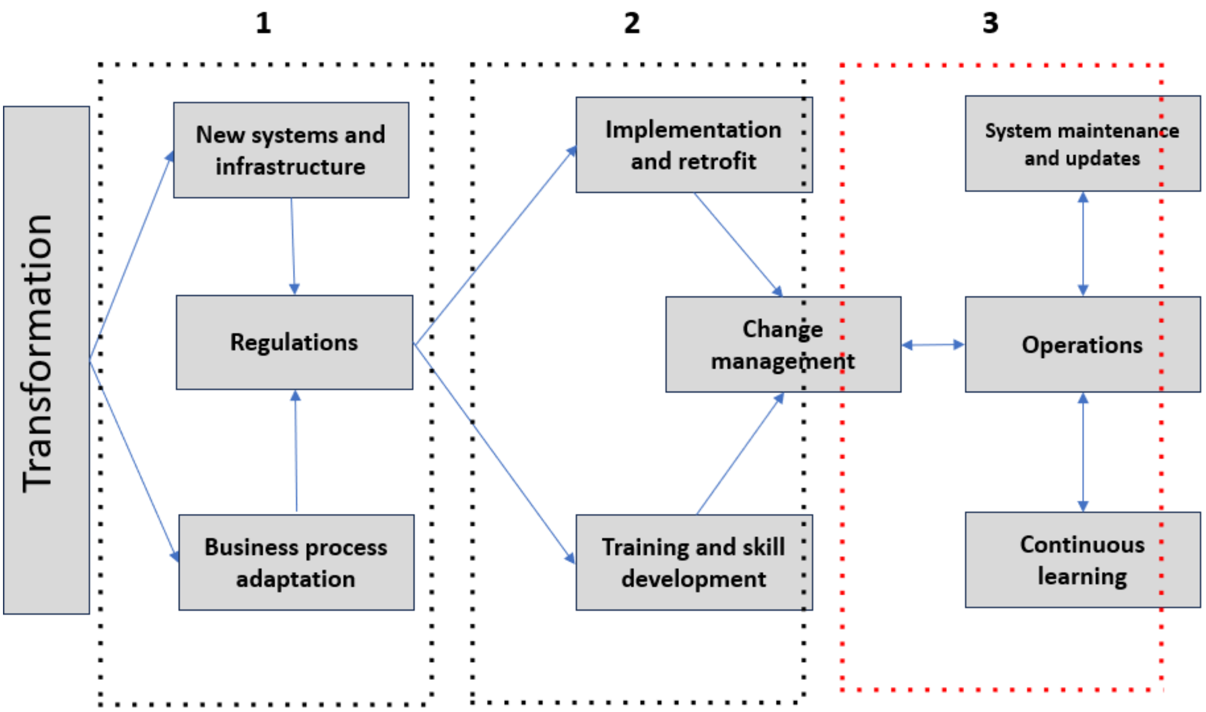

Figure 8 – Transformation process

In this review, the retrieved studies identified challenges arising primarily during the two initial stages of the transformation process illustrated in figure 8. These two phases are marked by temporary and transitional changes. Although these phases are fundamental for the successful integration of technologies, inadequate preparation for operational shifts and permanent organizational adjustments can limit the realization of anticipated benefits, potentially leading to suboptimal outcomes. Consequently, there's a need for researchers to explore the transition from ERTMS, RTC, and ATO projects into the operational landscape of railway operators. This exploration is necessary for mitigating the challenges associated with permanent organizational transformation triggered by the introduction of novel digital technologies.

Future research should also dive into the supplier-operator relationship, especially in the case of RTC and ATO. Further research should seek to distinguish the challenges arising from different project phases in the case of ERTMS, RTC and ATO, since, in the retrieved literature, no distinction has been made. More research on the interactions between these technologies is needed, as well as more attention on RTC, which was underexplored in the retrieved literature. In closing, the research sheds light on the critical intersection of change management and digitalization within the railway industry. By considering ERTMS, RTC and ATO projects within the broader organizational context, this study provides valuable insights for practitioners, researchers, and policymakers alike. As the railway sector navigates the challenges and opportunities presented by digital technologies, understanding and addressing the managerial aspects become imperative for successful and sustainable implementations. Future research in this domain should continue to explore and refine management strategies tailored to the evolving landscape of digitalization projects in the railway industry.

Acknowledgements and Funding

The activity hereby described is part of the FP2 R2DATO project, which is partially funded by the European Commission through the Europe's Rail Joint Undertaking under the Horizon Europe Programe with the grant agreement no 101102001. Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EU Rail. Neither the European Union nor the granting authority can be held responsible for them.

Conflict of Interest and Ethical Statement

This research was conducted in accordance with the highest ethical standards. The authors have no conflicts of interest to declare.

Authors Contributions

Conceptualization, Xavier Morin; Methodology, Xavier Morin; Supervision, Nils Olsson and Albert Lau; Validation, Xavier Morin; Writing – original draft, Xavier Morin; Writing – review & editing, Xavier Morin, Nils Olsson and Albert Lau.

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