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Investigating the Technical Skills Needed to Improve Rail Network Performance

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Abstract

The railway industry is complex and relies on highly skilled professionals to enhance its performance. However, it faces significant challenges due to a notable skill gap in critical areas such as engineering and management. A comprehensive literature review was undertaken to identify essential skills and strategies for addressing this gap. Additionally, a qualitative research study consisting of a focus group discussion with industry experts was conducted to establish the interrelationship between critical skills and the various strategies for addressing the skill gap through interpretive structural modeling. MICMAC analysis determined the driving and dependence power among the critical skills and strategies. The data was analyzed using Microsoft Excel. The findings revealed a strong relationship among the essential skills and strategies identified in the literature review and focus group discussions, all of which are directly related to the railway industry. The most severe skill shortages were found in civil, structural, electrical, and mechanical engineering. The study highlights the need for the South African railway industry to address the skill gap to improve its performance and meet the increasing demands of the sector.

Keywords
Railway Industry, Critical Skills, Skills Gap, Interpretive Structural Modelling, and MICMAC

1. Introduction

The railway transport industry is a vital economic driver in South Africa due to its environmentally friendly nature and its ability to efficiently transport large quantities of freight and passengers (Mukwena et al., 2019). The South African Rail Network Company is currently facing challenges in performance, including declining volume performance and failure to meet target volumes. For the 2021–2022 financial year (FY), the total volume performance was 172.7 million tonnes (mt), marking a 5% decrease from the previous year's total of 181.1 mt in volume performance (2020/2021). Moreover, the targeted volumes for FY 2021–2022 were 208.8 mt, while the actual achieved volumes were 172.7 mt (Transnet Railway Company, 2022). South African commuter rail companies are also grappling with widespread operational disruptions. The advanced age of the trains, which have surpassed their 33-year lifespan, and a shortage of skilled workers are the primary reasons for poor service delivery in the passenger rail industry (Chimusoro et al., 2017).

As per Galagan (2009), the existing skills gap in the workforce can impede organizational performance and hinder productivity. A skills gap arises when there is a shortage of necessary skills to meet company objectives, and the current workforce lacks the proficiency to carry out their responsibilities (Morris & Reed, 2008). Technical skills refer to job-specific competencies required to complete specific tasks or the ability to execute a particular task by utilizing the requisite skills (Green, 2005; Manjunath et al., 2019). The lack of adequate maintenance policies, plans, and implementations, along with a shortage of skilled personnel and skill gaps, are significant factors contributing to the failures in South Africa's railway infrastructure (Ramuhulu & Chiranga, 2018; Mukwena et al., 2019). According to

Mukwena et al. (2019), South Africa experiences a mismatch between educational requirements and available jobs, a significant labor shortage, and an overall scarcity of skilled workers.

The South African Rail Network Company introduced a voluntary severance package (VSP) during the 2016–2017 and 2021–2022 financial years, but the unfilled positions resulted in a skills gap and shortage within the organization, negatively impacting its performance. A substantial skills gap can lead to dissatisfaction within a business and is likely to affect the quality and quantity of the organization's output (Ramuhulu & Chiranga, 2018). This study analyzes the technical and critical skills required to enhance performance and offers recommendations for addressing the skill gap in the railway sector.

1.1 Objectives

The objectives of this study are as follows:

1) To identify the technical skills gap in the South African railway industry
2) To identify strategies to address the skills gap in the South African railway industry

2. Literature Review

Skill shortages and skills gaps present a significant challenge for the railway industry on a global scale (Fraszczyk et al., 2015). This is primarily due to difficulties in competing with the pay rates offered by other industries, both domestically and internationally, as well as heightened competition for workers resulting from ongoing construction and resource booms (Mahendran & Dockery, 2008). Currently, many railways are grappling with a substantial skill crisis attributed to the industry's cyclical downturn and subsequent rapid expansion, limited recruitment, an aging cohort of professional engineering staff, and a dearth of technical and engineering skills (Murray, 2011; Wallace et al., 2011; Cameron et al., 2013). Additionally, factors such as skill gaps, increasing retirement age, a shortage of highly experienced employees, and an aging workforce are all contributing to the scarcity of skilled rail engineering workers (Fraszczyk et al., 2015; Fraszczyk & Piip, 2020; Jiang, 2021).

2.1 Skills shortages or skills gap in the rail sector

The South African Rail Network Company's struggle with infrastructure breakdowns may be attributed to the country's existing shortage of engineering talent (Ramuhulu & Chiranga, 2018). Given the high level of specialization in the railway industry, there is a strong demand for management and engineering skills (Mukwena et al., 2019). Furthermore, it has been noted that the South African railway industry has limited knowledge of engineering standards for railways, limited experience in using additive materials in railway construction, and limited ability for design optimization (Bouraima et al., 2023).

A well-documented skills gap in the engineering sector particularly affects areas of specialization and general engineering skills, especially in rail engineering and signaling engineering (Cameron et al., 2013). According to Wallace et al. (2011), the most severe skill shortages are in civil, structural, electrical, and mechanical engineering, which are crucial to the railway industry. They also highlighted that civil, track, signaling, and electrical engineering are the specialties required for railway projects with the most serious skills gaps (Wise et al., 2011). Additionally, (Naweed et al., 2018) pointed out that the railway industry in Australia and the United States is also facing critical skill shortages, including an increasing scarcity of train drivers. Vital skill shortages in the railway industry include engineering, technical, and trade skills, as well as design and project management skills (Wise et al., 2011; Cameron et al., 2013). Lastly, (Chimusoro et al., 2017) asserted that the South African commuter rail system is grappling with a severe shortage of essential skills such as electrical engineers, mechanical engineers, signaling engineers, artisans, train drivers, and traffic control officers.

2.2 Strategies to close the skills gap in the rail sector

The railway industry presents unique challenges when it comes to skills transferability due to its highly specialized technical knowledge and complex operational environment (Wise et al., 2011). The integration of different disciplines within the railway system adds another layer of complexity (Wise et al., 2011). Work-based learning plays a crucial role in developing professional skills and addressing the shortage of engineering expertise in the industry (Wise et al., 2011). To bridge the skills gap, the Australian rail industry has explored various strategies, including the recruitment of skilled migrants and targeted education and training programs in rail engineering disciplines such as signaling, electrical systems, and track design (Wise et al., 2011; Cameron et al., 2013).

In addition, the establishment of learning factories can help address the disconnect between industry and academia by providing practical opportunities for skill development (Maheso et al., 2018). The railway industry experiences constant evolution, driven by technological advancements and innovation, making it challenging to find qualified candidates to fill open positions in its various departments. E-learning in engineering education effectively meets this demand, addressing the increasing need for railway engineering experts (Rajaonah et al., Feb 2018; Sitányiová & Mašek, 2018). SIGMA RAIL also contributes to bridging the skills gap in the railway industry by offering courses related to the field, such as assistant engineer in civil and electrical engineering and maintenance engineer in civil and electrical engineering (Rajaonah et al., Feb 2018). The demand for railway engineering specialists is growing globally, and strategic projects are being utilized to meet this demand (Sitányiová & Mašek, 2018). The railway sector is undergoing digitalization, impacting every aspect of the railway system. Digital learning, including emerging technologies and railway digitalization, is enhancing the skills of current and prospective rail employees, equipping them to keep pace with innovation (Fraszczyk & Piip, 2020).

3. Methods

The study used an action research approach and qualitative methods to collect data (Kothari, 2004; Saunders et al., 2009). Data was predominantly gathered through an online focus group with experts from the railway industry. Qualitative research is a method used to explore and comprehend the significance of individuals or groups related to a social or human issue. Additionally, the research process involves developing study questions and methods, gathering data (usually in the participant's environment), analyzing that data inductively (moving from specific to general themes), and evaluating the significance of the findings (Creswell, 2014). Action research is a method that combines both research and action. The research component of action research entails a systematic approach to information or data collection, often utilizing techniques common to qualitative research (Heigham & Croker, 2009). Action research aims to advance knowledge in the field of practice, while the action component focuses on improving practice (McNiff, 2016). Focus groups are a data collection method that generates much qualitative data with relatively minimal face-to-face researcher interaction (Parker & Tritter, 2006). According to (Plummer, 2017), focus groups are highly effective for exploring people's opinions, ideas, attitudes, and experiences on a specific topic.

Six individuals from the railway industry were invited to participate in virtual focus group discussions through calls and emails, and four of them ultimately participated. The discussions took place on Microsoft Teams. The study targeted line managers at the senior management level and above who oversee testing, maintenance, and execution of rail infrastructure projects.

4. Data Collection

The research methodology utilized in this study involved a comprehensive literature review, focus group discussions to gather additional participant data, and the application of interpretive structural modeling (ISM) and MICMAC techniques to fulfill the research objectives. ISM and MICMAC techniques were manually applied using Microsoft Excel. The data collection process for this study followed these steps:

1. The literature review identified critical skills for the railway industry, including train driving skills, civil, electrical, and signaling engineering skills, project management skills, technical specialist skills, design management skills, and drafting skills. The review also revealed strategies to address the skills gap in the railway industry, such as recruiting top talent, facilitating workplace learning, hiring skilled migrants, providing education and training in rail engineering, establishing learning factories, utilizing e-Learning (SIGMA Rail), implementing skillful projects, and embracing new technology and rail digitalization.

2. During the focus group discussion with railway industry experts, we identified several critical skills, including mechanical, industrial, and structural engineering, as well as management (leadership, communication), maintenance management, technical specification, and analytical skills. We also discussed strategies such as mentorship programs, discipline-specific task strategies, performance management, learning progression, succession plans, updated training matrices, ICT systems, railway undergraduate programs, compensation, rewards, and acknowledgments, and fostering a culture of belonging. The interpretive structural modeling technique was used to determine the relationships between these critical skills and various strategies to address the skills gap, and the MICMAC analysis helped determine the driving power and dependence power between them.

3. The ISM technique involves identifying the key components of the system. In this study, these components are the enablers, which encompass critical skills for the railway industry and strategies for mitigating the skills gap in this sector. Once the enablers are established, the connections between the critical skills and the strategies for addressing the skills gap are determined. A structural self-interaction matrix (SSIM) is then created through pairwise comparisons of the identified enablers (Attri, 2017; Sharma et al., 2021). The relationships between any two critical skills and any two strategies for addressing the skills gap in the railway industry are denoted by the symbols V, A, X, and O. The next step in the ISM approach involves using the SSIM to generate an initial reachability matrix, in which the symbols (V, A, X, and O) are replaced with binary digits (1 and 0) (Attri, 2017; Sharma et al., 2021).

4. The transitivity of the initial reachability matrix is analyzed to establish the final reachability matrix. A value of 1 indicates the presence of a contextual relationship between two items, while a value of 0 signifies the absence of such a relationship. Transitivity-related relationships are denoted by the symbol 1* (Kusrini et al., 2019; Sharma et al., 2021). The elements are then partitioned, and the ISM model is derived from the final reachability matrix (Attri, 2017). Level partitioning is used to identify the different levels in the ISM model based on the acquired final reachability matrix (Sharma et al., 2021).

5. The final step involves conducting MICMAC analysis, where MICMAC stands for Matrice d'Impacts cross-multiplication application and classment (Attri, 2017; Sharma et al., 2021). The MICMAC analysis assesses the driving and dependence power of the factors under investigation and categorizes them into four groups: autonomous enablers, linkage enablers, dependent enablers, and independent enablers (Attri, 2017; Kusrini et al., 2019; Sharma et al., 2021).

Autonomous enablers are somewhat separated from the system since they have weak driving and dependence powers and few linkages to the system, even though those links may be pretty intense (Attri, 2017; Kusrini et al., 2019; Sharma et al., 2021). Dependent enablers have weak driving power and strong dependence power (Attri, 2017; Kusrini et al., 2019; Sharma et al., 2021). Linkage enablers possess both strong driving power and strong dependence power. Furthermore, enablers are unstable since any response they receive will impact others and give feedback on themselves (Attri, 2017; Kusrini et al., 2019). Independent factors strongly influence the system because they have strong driving power but weak dependence power (Attri, 2017; Kusrini et al., 2019; Sharma et al., 2021).

5. Results and Discussion

5.1 Critical Skills for the Railway Industry

The final reachability matrix for the critical skills in the railway industry is shown in Table 1 below. The value of 1 shows a relationship between critical skills, 0 shows no relationship between critical skills, and 1* denotes transitivity relationships.

The data presented in Table 1 indicates that train driving skills only impact themselves (denoted by 1) and do not influence other critical skills (denoted by 0). Essential skills such as civil, electrical, signaling, mechanical, industrial, and structural engineering impact all other necessary skills, including themselves (denoted by 1s). Project management skills have a direct influence on management skills, while management skills impact train driving skills, project management skills, design management skills, and drafting skills. This demonstrates that project management skills indirectly influence train driving, design management, and drafting skills through transitivity. Drafting skills have a direct influence on project and maintenance management skills (denoted by 1s) and indirectly influence train driving skills and management skills through transitivity (denoted by 1*s). Technical specialist, design management, and analytical skills have both direct and indirect influences (through the transitivity rule) on all other critical skills. The ISM model for critical skills in the railway industry is depicted in Figure 1.

Table 1. Final Reachability Matrix for Critical Skills in the Railway Industry

Enabler	Description	E1	E2	E3	E4	E5	E6	E7	E8	E9	E 10	E 11	E 12	E 13	E 14	E 15
E1	Train driving Skills	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	Civil Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E3	Electrical Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E4	Signalling Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E5	Project Management Skills	1*	0	0	0	1	0	1*	1*	0	0	1	0	0	0	0
E6	Technical Specialist Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1*	1
E7	Design Management Skills	1	1	1	1	1	1*	1	1	1	1	1*	1	1*	1*	1
E8	Drafting Skills	1*	0	0	0	1	0	0	1	0	0	1*	1	0	0	0
E9	Mechanical Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E10	Industrial Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E11	Management Skills	1	1*	1*	1*	1	0	1	1	1*	1*	1	1*	0	0	1*
E12	Maintenance Management Skills	1	0	0	0	1	0	1*	1*	0	0	1	1	0	0	0
E13	Technical Specification Skills	1	1*	1*	1*	1	1*	1	1	1*	1*	1	1	1	1	1*
E14	Analytical Skills	1	1*	1*	1*	1	1	1	1	1*	1*	1	1	1*	1	1*
E15	Structural Engineering Skills	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The critical skills at level 4 of the ISM model, including civil, electrical, signalling, mechanical, industrial, and structural engineering, as well as technical specialist, technical specification, and analytical skills, have a significant influence on each other. These skills also impact design management, maintenance management, project management, drafting, management, and training driving skills at levels 3, 2, and 1 of the ISM model. Design management and maintenance management skills at level 3 of the ISM model mutually influence each other and also have an impact on project management skills, drafting skills, and management skills at level 2 of the ISM model. Similarly, project management, drafting, and management skills influence each other and impact train driving skills at level 1 of the ISM model. Train driving skills at level 1 are influenced by all other critical skills at levels 2, 3, and 4 of the ISM model. These findings suggest that fundamental skills at lower levels of the ISM model significantly influence critical skills at the upper level of the ISM model, and vice versa. The driving power and dependence power of the critical skills in the railway industry, as determined through the MICMAC analysis, are presented in Table 2 below.

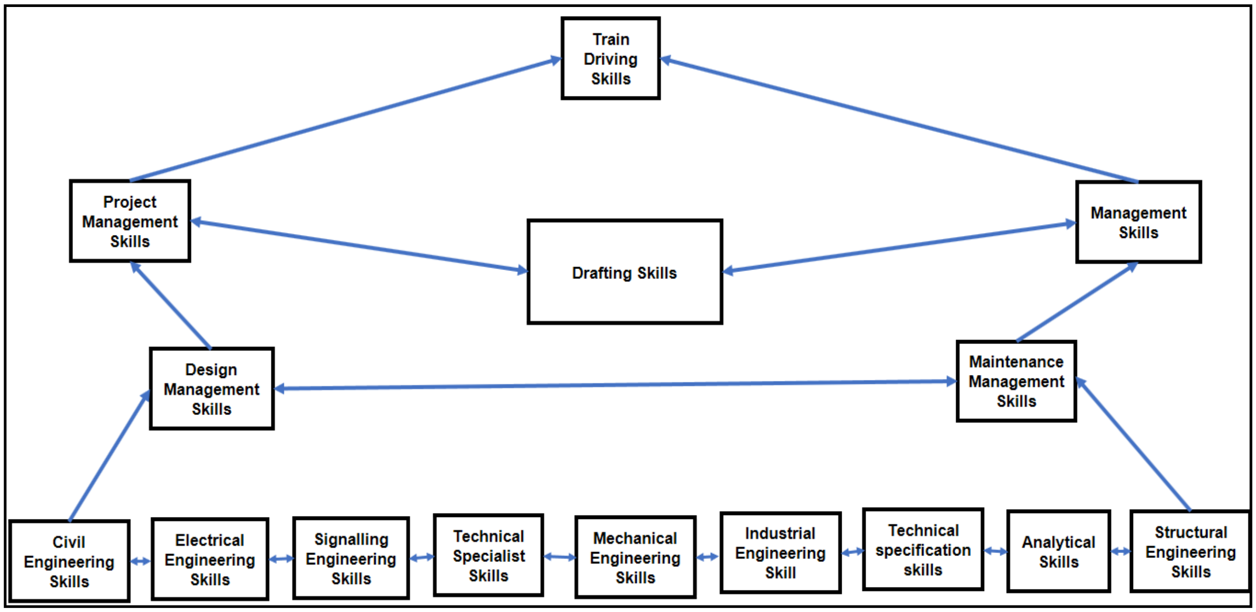

Figure 1. ISM Model for Critical Skills in the Railway Industry

Table 2. MICMAC Analysis for Critical Skills in the Railway Industry (Sharma et al., 2021)

Quadrant	**Name of Factor/Enabler**	**Level in ISM Model**	**Code of Enabler**	**Name of Enabler**
Quadrant I	Autonomous Enablers (Weak Drive Power and Weak Dependence Power)	There are no enablers in this quadrant		
Quadrant II	Dependent Enablers (Weak Drive Power and Strong Dependence Power)	Level 1	E1	Train driving Skills
		Level 2	E5	Project Management Skills
		Level 2	E8	Drafting skills
		Level 3	E12	Maintenance Management Skills
Quadrant III	Linkage Enablers (Strong Drive Power and Strong Dependence Power)	Level 2	E11	Management Skills
		Level 3	E7	Design Management Skills
		Level 4	E6	Technical Specialist Skills
		Level 4	E13	Technical Specification Skills
		Level 4	E14	Analytical Skills
		Level 4	E2	Civil Engineering Skills
		Level 4	E3	Electrical Engineering Skills
		Level 4	E4	Signalling Engineering Skills
		Level 4	E9	Mechanical Engineering Skills
		Level 4	E10	Industrial Engineering Skills
		Level 4	E15	Structural Engineering Skills
Quadrant IV	Independent Enablers (Strong Drive Power and Weak Dependence Power)	There are no independent enablers in this quadrant		

The findings in Table 2 indicate that all the essential skills identified in this study are directly relevant to the railway industry. There are no crucial skills with weak driving and weak dependence power, meaning there are no autonomous enablers. Skills such as train driving, project management, drafting, and maintenance management are considered essential and possess weak drive power and strong dependence power, making them dependent enablers. On the other hand, critical skills such as civil, electrical, signaling, mechanical, industrial, and structural engineering, as well as technical specialist, design management, technical specification, management, and analytical skills, have solid drive power and dependence power, categorizing them as linkage enablers. It's important to note that any minor alterations in these skills can significantly impact others and even themselves, given their inherent instability. Lastly, no critical skills with solid drive power and weak dependence power (independent enablers) were identified in this study.

5.2 Strategies to Address the Skills Gap in the Railway Industry

The final reachability matrix for the strategies to address the skills gap in the railway industry is shown in Table 3 below.

Table 3. Final Reachability Matrix for Strategies to Address the Skills Gap in the Railway Industry

Enabler	Description	E1	E2	E3	E4	E5	E6	E7	E8	E9	E1	E1	E1	E1	E1	E1	E1	E1	E1
E1	Recruitment of the Best Employees	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2	Workplace Learning	1	1	1*	1	1	1	1*	0	1*	0	1	1	0	1	1*	1*	1	1
E3	Recruitment of Onshore Skilled Migrants	1	1*	1	1*	1	1	1	0	0	0	1*	1*	0	1*	1*	1*	1*	1*
E4	Education and Training in Rail Engineering	1	1	1	1	1	1	1	0	1*	0	1	1	0	1	1	1*	1	1
E5	Learning Factories	1	1	1*	1	1	1	1	1*	1*	1*	1	1	0	1	1*	1	1	1
E6	e-Learning (SIGMA Rail)	1*	1	0	1*	1*	1	1*	0	0	0	1	1*	0	1*	0	0	1	1
E7	Skillful Project	1	1	1*	1	1*	1	1	0	0	0	1*	1	0	1*	1	0	1	1
E8	New Technology and Rail Digitalization	1	1	1	1	1	1	1	1	1*	0	1	1	0	1	1	1*	1*	1*
E9	Mentorship Programme	1*	1	1*	1	1	1	1	1	1	1*	1	1	0	1*	1	1	1*	1*
E10	Discipline-Specific Task Strategy	1*	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1*	1	1
E11	Performance Management	1*	1*	0	1*	0	1*	1	0	1*	0	1	1*	0	1	1*	0	1	1*
E12	Learning Progression	0	1*	0	1*	1*	1	1*	0	1*	0	1	1	0	1	1	0	1	1
E13	Succession Plan	1*	1	1*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E14	Updated Training Matrix	1*	1	0	1*	1*	1	1	1*	1	0	1*	1*	0	1	1*	1*	1	1
E15	ICT Systems	1*	1	1*	1	1	1	1*	0	1*	0	1	1*	0	1	1	1*	1	1
E16	Railway Undergraduate Programmes	1*	1	1*	1	1*	1	1	1	1*	1	1	1	0	1	1	1	1	1
E17	Compensation, Rewards, and Acknowledgment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
E18	Culture of belonging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

The results from Table 3 above demonstrate that the strategy for recruiting the best employees only influences itself, as indicated by a 1, and has no influence on other strategies, as noted in a 0. The same applies to the strategies of compensation, rewards, and Acknowledgment as well as the strategy of the culture of belonging; however, the strategies of compensation, rewards, and Acknowledgment also impact the strategy of the culture of belonging.

The recruitment of the best employees, education and training in rail engineering, learning factories, e-learning (SIGMA Rail), performance management, learning progression, an updated training matrix, compensation, rewards, and Acknowledgment, as well as a culture of belonging as denoted by 1s, are all directly influenced by workplace learning. Through transitivity, workplace learning indirectly influences the recruitment of skilled onshore immigrants, skillful projects, mentorship programs, ICT systems, and undergraduate railway programs, as indicated by the 1*s. Still, it does not influence new technology and rail digitalization, discipline-specific tasks strategy, or succession plan, as noted in the 0s.

The succession plan directly influences all other railway industry strategies, as indicated by 1s, and indirectly influences the recruitment of the best employees and the recruitment of onshore skilled migrants through transitivity, as indicated by 1*s. Figure 2 below shows the ISM model for strategies to address the skills gap in the railway industry.

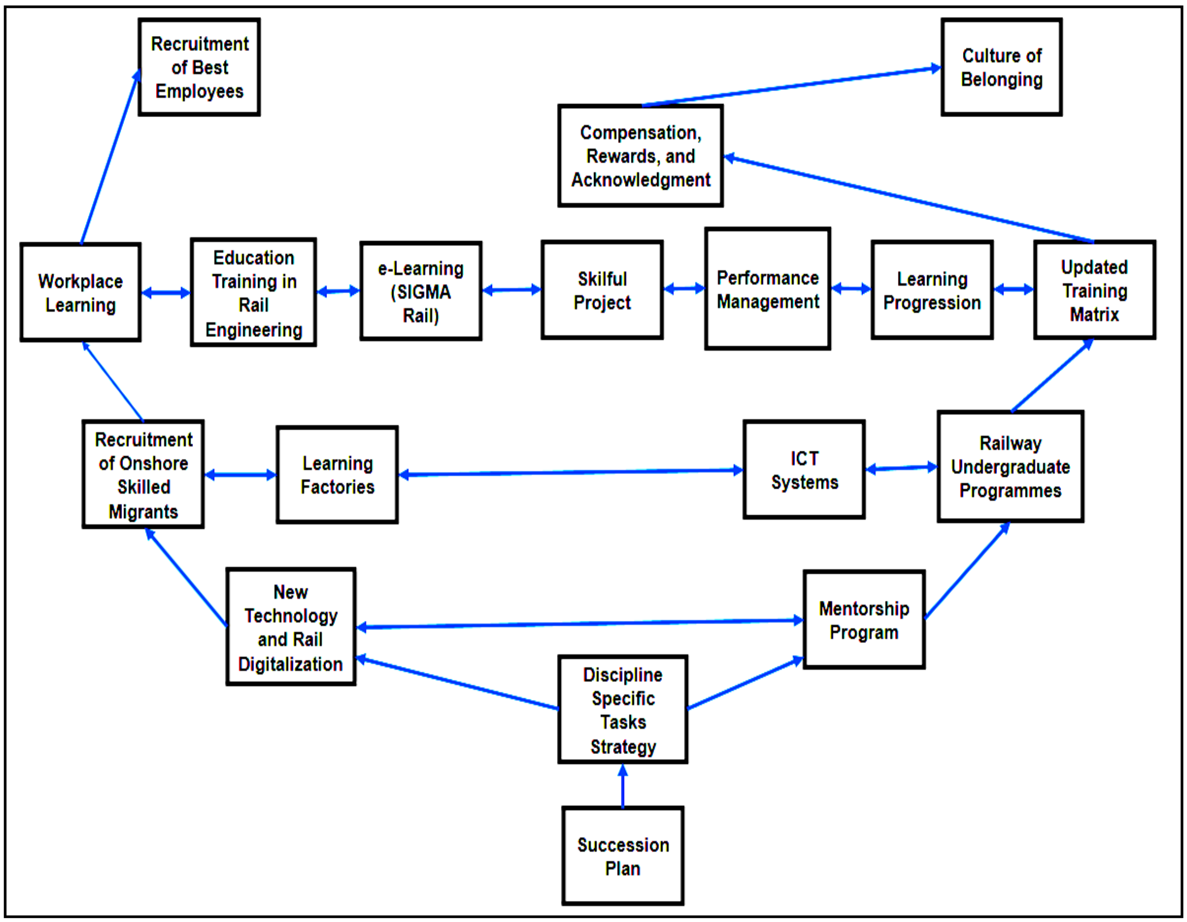

Figure 2. ISM Model for Strategies to Address the Skills Gap in the Railway Industry

As mentioned before, the strategies at the lower levels of the ISM model have more influence on the upper levels and vice versa. This means that the succession plan strategy in level 7 influences the discipline-specific task strategy in level 6, and the discipline-specific task strategy influences new technology and rail digitalization strategies and mentorship program strategies in level 5. The recruitment of onshore skilled migrants, learning factories, ICT systems, and railway undergraduate program strategies at level 4 is influenced by the new technology and rail digitalization strategy and mentorship program at level 5 of the ISM model. The strategies in Level 5 also influence each other. The recruitment of onshore skilled migrants, learning factories, ICT systems, and railway undergraduate program strategies all influence each other. They also influence workplace learning, education training in rail engineering, e-learning (SIGMA Rail), skillful projects, performance management, learning progression, and updated training matrix strategies in level 3.

Workplace learning, education training in rail engineering, e-learning (SIGMA Rail), skillful projects, performance management, learning progression, and updated training matrix strategies all have an influence on one another as well as on compensation, rewards, and Acknowledgment, recruitment of the best employees, and a culture of belonging in levels 2 and 1 of the ISM model. All other strategies in levels 3, 4, 5, 6, and 7 of the ISM model influence the recruitment of the best employees, culture of belonging, compensation, rewards, and acknowledgment strategies. The driving power and dependence power of the approach to address the skills gap in the railway industry determined through the MICMAC analysis are shown in Table 4 below.

Table 4. MICMAC analysis for strategies to address the skills gap in the railway industry (Sharma et al., 2021)

Quadrant	**Name of Factor/Enabler**	**Level in ISM Model**	**Code of Enabler**	**Name of Enabler**
Quadrant I	Autonomous Enabler (Weak Drive Power and Weak Dependence Power)	There are no enablers in this quadrant		
Quadrant II	Dependent Enablers (Weak Drive Power and Strong Dependence Power)	Level 1	1	Recruitment of the Best Employees
		Level 1	18	Culture of belonging
		Level 2	17	Compensation, Rewards, and Acknowledgment
Quadrant III	Linkage Enablers (Strong Drive Power and Strong Dependence Power)	Level 3	6	e-Learning (SIGMA Rail)
		Level 3	11	Performance Management
		Level 3	12	Learning Progression
		Level 3	7	Skillful Project
		Level 3	2	Workplace Learning
		Level 3	4	Education and Training in Rail Engineering
		Level 3	14	Updated Training Matrix
		Level 4	3	Recruitment of Onshore Skilled Migrants
		Level 4	15	ICT Systems
		Level 4	16	Railway Undergraduate Programmes
		Level 4	5	Learning Factories
		Level 5	9	Mentorship Programme
Quadrant IV	Independent Enablers (Strong Drive Power and Weak Dependence Power)	Level 5	8	New Technology and Rail Digitalization
		Level 6	10	Discipline-Specific Task Strategy
		Level 7	13	Succession Plan

The results in Table 4 above also show that all the strategies to address the skills gap in the railway industry identified in this study are related to the railway industry, as there are no autonomous enablers. The dependent enablers with weak driving power and strong dependence power found in this study are recruitment of the best employees, a culture of belonging, and compensation, rewards, and acknowledgment strategies. Strategies to address the skills gap in the railway industry with solid drive power and strong dependence power (linkage enablers) are e-learning (SIGMA Rail), performance management, learning progression, skillful project, workplace learning, education training in rail engineering, an updated training matrix, recruitment of onshore skilled migrants, ICT systems, railway undergraduate programs, learning factories, and a mentorship program. Since they are unstable, any slight change in these strategies will impact other strategies and even themselves.

The independent enablers with solid drive power and weak dependence power found in this study are new technology and rail digitalization, discipline-specific task strategies, and a succession plan. These strategies possess strong driving power and don't depend much on other strategies. These strategies are the key drivers behind the development of effective strategies and act as the foundation for different strategies to address the skills gap in the railway sector.

5.3. Proposed Improvements

The railway companies are faced with limited resources and are unable to invest in all critical skills and strategies to address the skills gap simultaneously. Consequently, they must prioritize certain essential skills and techniques. The findings indicate that engineering skills (civil, electrical, signaling, mechanical, industrial, and structural), technical specialist skills, technical specification skills, and analytic skills have a greater impact on other critical skills. Professionals with engineering skills can also serve as technical specialists, project managers, design managers, and maintenance managers, in addition to possessing technical specification and analytic skills. Therefore, railway companies should prioritize civil, electrical, signaling, mechanical, and industrial skills, as they are crucial for designing, testing, maintaining railway infrastructure, and carrying out rail projects. Furthermore, electrical, mechanical, and industrial engineers can be involved in testing and maintaining rolling stock. The study reveals that train driving skills do not significantly influence other critical skills, but train drivers play a vital role in transporting passengers and freight. Professionals like drafters and structural engineers are primarily needed during the design and construction phases of projects. Consequently, companies can acquire these skills on a temporary basis as needed.

Internal strategies to address the skills gap, such as succession planning, discipline-specific strategies, mentorship programs, workplace learning, an updated training matrix, and railway undergraduate programs, should be given priority, as they can be implemented internally without requiring additional funds. Performance management should also be prioritized to encourage skilled workers to transfer their knowledge to younger employees. On the other hand, recruiting the best employees and onshore skilled migrants should be of lower priority, as these initiatives will necessitate additional funding, which may pose challenges for other companies.

5.4. Validation

In this study, we conducted a comprehensive literature review to identify critical skills and strategies for addressing the skills gap in the railway industry. Additionally, we engaged experts from the railway industry to contribute any additional essential skills and strategies that may not have been captured in the literature review. This approach ensured that we met the criteria for content validity by encompassing a broad range of relevant content.

6. Conclusion

The South African railway industry is facing significant challenges due to a notable skill gap in critical areas such as engineering and management, leading to declining performance and failure to meet target volumes. This study aims to identify the technical skills gap and strategies to address it in the South African railway industry. A comprehensive literature review and a qualitative research study consisting of a focus group discussion with industry experts were conducted. Interpretive structural modeling was used to establish the interrelationship between critical skills and strategies, while MICMAC analysis determined the driving and dependence power among them. The findings revealed a strong relationship among the essential skills and strategies identified, all of which are directly related to the railway industry. The study concludes that railway companies must prioritize these critical skills and strategies to bridge the skill gap and enhance their operations and performance. The most severe skill shortages were found in civil, structural, electrical, and mechanical engineering, as well as in specialties such as civil, track, signaling, and electrical engineering. The study highlights the need for the South African railway industry to address the skill gap to improve its performance and meet the increasing demands of the sector.

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