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Multi-Attribute Decision-Making for Intelligent Allocation of Human Resources in Industrial Projects

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Abstract: Effective project management depends on a deep understanding of the human attributes that influence project success. This study aims to quantify the causal relationships between human resource variables in order to establish a prioritisation criterion for workforce allocation in industrial projects. Traditional statistical models often overlook the multidimensional nature of these factors, limiting their effectiveness in complex planning contexts. To address this, the Decision-Making Trial and Evaluation Laboratory method is used to assess and prioritise the key competencies required of project personnel. The analysis is based on an extensive literature review of management and industrial project studies, combined with data collected from experienced managers through structured questionnaires. Respondents assessed how different human resource attributes interact and influence each other. The results show that personal motivation, innovation, education, work–life balance, flexibility and adaptability are dominant causal factors. Stakeholder relations, conflict management, negotiation skills, objectivity and impartiality are more reactive. This study is differentiated in that it analyses a complex network of 400 influence relationships, providing a more comprehensive perspective than previous research. By integrating a structured decision-making approach, the results contribute to both the academic literature and practical applications, supporting more effective workforce planning and improved performance in industrial projects.

Keywords: human resource optimisation; project planning; DEMATEL methodology; industrial project management; workforce allocation; strategic competency mapping; organisational performance

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1. Introduction

In the context of industrial organisations, effective management of human resources, especially in the planning phase, contributes significantly to the achievement of project objectives. European science and innovation programmes face a significant failure rate (Bader et al., 2024), with around 20% of transnational research projects failing to achieve their objectives due to resource conflicts (Dong & Qiu, 2024). What is even more concerning is that 75% of these projects never reach the implementation phase

(James & Frank, 2015), suggesting a systemic problem at the EU level. Studies show that the success of these projects depends largely on human factors (Amiri et al., 2021; de la Puente Pacheco et al., 2024; M. S.-M. Lin & Lu, 2023; Salih et al., 2022; Wuni et al., 2022), making human resource management (HRM) a major issue. Problems such as inefficient allocation of tasks (Abdullahi et al., 2022; Al-aloosy et al., 2024; Dong & Qiu, 2024; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021), mismatch of team skills with project requirements (Abdullahi et al., 2022; Al-aloosy et al., 2024; Dong & Qiu, 2024; Romulo et al., 2022; Vrchota & Řehoř, 2021; Wuni et al., 2022) and failure to meet deadlines can lead to delays (Deselnicu et al., 2023; Dong & Qiu, 2024; Estiri et al., 2021), additional costs and non-performance, with a negative impact on the economy (Chiriță et al., 2021).

There is a consensus that a systematic approach to HRM is more effective than a one-dimensional one (James & Frank, 2015). However, there is still no agreement on the best combination of practices to build a high-performing system (Amiri et al., 2021; Barak & Dahooei, 2018; Estiri et al., 2021; Yazdani et al., 2019). Given the complexity of the factors involved in project success, traditional statistical models are proving inadequate for analysing project performance from an HRM perspective (Romulo et al., 2022). In general, the analysis of human resource performance in project management has been based on statistical methods that assume linear and independent relationships between variables. However, organisational reality is much more complex and the success of a project depends not only on individual factors but also on the interactions between them. Multi-attribute decision-making methods (MADMs) have been extensively studied in the literature, but their practical application is still diverse and there is still no near-standard approach (Estiri et al., 2021; James & Frank, 2015). MADMs are more suitable for this analysis because they allow the simultaneous consideration of multiple attributes, including conflicting or interdependent factors. The use of MADMs, which allow the evaluation of a complex set of criteria, including conflicting ones, can provide a valuable reference framework to support decision-making in team planning in industrial organisations.

Given this background, the present study seeks to address the following research question: How can the causal relationships between human resource attributes be identified and prioritised in order to improve the allocation of project personnel in industrial organisations? Accordingly, the main objective of this research is to quantify the interdependencies between key human resource factors and to develop a prioritisation criterion to support strategic workforce planning. The aim is to provide a structured decision-making framework that is both comprehensive and adaptable to the complexity of industrial project environments.

Due to the multidimensional nature of human resources (HR), methods such as Step-Way Weighting Ratio Analysis (SWARA), the Analytic Hierarchical Process (AHP) and the Best–Worst Method (BWM) are not suitable for determining the relative importance of HR outcomes and their impact on the allocation of human resources in projects, as they focus on providing a single outcome or set of outcomes as a result of an analysis of multiple attributes (Estiri et al., 2021). Among the available MADMs, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) was chosen because it prioritises factors and identifies causal relationships between them, allowing a deeper understanding of how HR capabilities influence project success. The DEMATEL technique differs from other MADMs in that it provides a matrix framework for analysing the causal relationships between different factors, making it a valuable strategic management tool. This matrix framework can be used to identify interdependencies between variables and to gain a deeper understanding of how each factor influences overall performance. An additional advantage of DEMATEL is that it provides a useful tool for indirectly improving critical factors in situations where

direct influence is not possible. By strengthening the determinants that have an impact on a key driver, a systemic improvement can be achieved (Estiri et al., 2021; Sun, 2021). Unlike other MADMs that focus on identifying a single critical factor or choosing the best option, DEMATEL allows for a more holistic and dynamic approach that takes into account the interactions between factors. This makes DEMATEL particularly useful in human resource analysis, where the complexity and variability of the influencing factors are high and the solutions must be flexible and personalised. Thus, the main difference between DEMATEL and other MADM techniques is that DEMATEL does not limit itself to selecting an optimal option but builds a detailed model of the interaction between factors.

2. Theoretical Framework

DEMATEL excels at visualising and interpreting cause–effect relationships within a set of criteria, allowing the identification of the most important determinants and dependent factors. This ability to map the complex web of influences between human resource characteristics makes DEMATEL a valuable tool for understanding and optimising the allocation of human resources in projects (Estiri et al., 2021).

Key Factors Assessed

The factors included in the DEMATEL methodology have been extracted from the literature, from HRM studies but also from research articles from different fields tangentially related to project management. Each examined factor has been assigned a symbolic code ranging from A to T. These are presented in Table 1.

Table 1. Factors included in the DEMATEL analysis.

Code	Factor	References
A	Educational level	(Abdullahi et al., 2022; Al-aloosy et al., 2024; Barbu et al., 2023; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Nazemi et al., 2020; Oproiu & Lițoiu, 2019; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021)
B	Technical competencies	(Akram & Habib, 2024; Idrees et al., 2022; Salih et al., 2022; Schopmeyer et al., 2024; Wang et al., 2024)
C	Experience in similar activities	(Abdullahi et al., 2022; Akram & Habib, 2024; Al-aloosy et al., 2024; Dong & Qiu, 2024; Estiri et al., 2021; Kukhareva et al., 2024; M. S.-M. Lin & Lu, 2023; Romulo et al., 2022; Sun, 2021; Vrchota & Řehoř, 2021; Wuni et al., 2022)
D	Spirit of innovation	(Abdullahi et al., 2022; Barbu et al., 2023; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Estiri et al., 2021; Gray et al., 2020; Nazemi et al., 2020; Salih et al., 2022; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021; Wang et al., 2024; Wuni et al., 2022)
E	Flexibility and adaptability	(Abdullahi et al., 2022; Åhlfeldt et al., 2023; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Estiri et al., 2021; Evans et al., 2022; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Salih et al., 2022; Schopmeyer et al., 2024; Sulamo et al., 2021; Sun, 2021; Wang et al., 2024; Wuni et al., 2022)
F	Personal motivation	(Aghamir, 2024; Åhlfeldt et al., 2023; Al-aloosy et al., 2024; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Evans et al., 2022; James & Frank, 2015; Kukhareva et al., 2024; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Romulo et al., 2022; Salih et al., 2022; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021; Wuni et al., 2022)
G	Interest in the project	(Al-aloosy et al., 2024; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Estiri et al., 2021; Kukhareva et al., 2024; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Vrchota & Řehoř, 2021; Wuni et al., 2022)

Table 1. *Cont.*

Code	Factor	References
H	Time management skills	(Aghamir, 2024; Akram & Habib, 2024; Farooq et al., 2022; Gray et al., 2020; M. S.-M. Lin & Lu, 2023; Scarneo-Miller et al., 2024; Schmalzl et al., 2022; Schopmeyer et al., 2024; Sulamo et al., 2021; Velasco et al., 2023; Yongdong et al., 2024)
I	Team dynamics—coordination	(Abdullahi et al., 2022; Aghamir, 2024; Åhlfeldt et al., 2023; de la Puente Pacheco et al., 2024; Estiri et al., 2021; Evans et al., 2022; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Salih et al., 2022; Schmalzl et al., 2022; Schopmeyer et al., 2024; Sulamo et al., 2021; Sun, 2021; Sundararajan & Madhavi, 2023; Wuni et al., 2022)
J	Objectivity and impartiality	(Kos & Mažgon, 2025)
K	Negotiation skills	(Chun et al., 2025; Estiri et al., 2021)
L	Conflict management	(Abdullahi et al., 2022; Al-aloosy et al., 2024; Appoh & Yunusa-Kaltungo, 2022; Davis et al., 2022; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Romulo et al., 2022; Salih et al., 2022; Scarneo-Miller et al., 2024; Siokas et al., 2021; Sun, 2021)
M	Stakeholder relationships	(Al-aloosy et al., 2024; Dong & Qiu, 2024; Nazemi et al., 2020; Salih et al., 2022; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021)
N	Transparency in communication	(Al-aloosy et al., 2024; Appoh & Yunusa-Kaltungo, 2022; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Isac & Waqar, 2016; Nazemi et al., 2020; Schmalzl et al., 2022; Sundararajan & Madhavi, 2023; Velasco et al., 2023; Vrchota & Řehoř, 2021)
O	Team climate of trust	(Brutu & Mihai, 2017; de la Puente Pacheco et al., 2024; Romulo et al., 2022; Vrchota & Řehoř, 2021; Wang et al., 2024)
P	Engaging in lifelong learning	(Abdullahi et al., 2022; C.-M. Alexe & Alexe, 2021; de la Puente Pacheco et al., 2024; Evans et al., 2022; Fleaca et al., 2023; Nazemi et al., 2020; Romulo et al., 2022; Salih et al., 2022; Sundararajan & Madhavi, 2023; Vrchota & Řehoř, 2021; Wuni et al., 2022)
Q	Strategic planning skills	(Abdullahi et al., 2022; Aghamir, 2024; Åhlfeldt et al., 2023; Akram & Habib, 2024; Al-aloosy et al., 2024; Appoh & Yunusa-Kaltungo, 2022; Davis et al., 2022; de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Estiri et al., 2021; Farooq et al., 2022; Gray et al., 2020; Kukhareva et al., 2024; Romulo et al., 2022; Salih et al., 2022; Schmalzl et al., 2022; Siokas et al., 2021; Sulamo et al., 2021; Sun, 2021; Velasco et al., 2023; Vrchota & Řehoř, 2021; Wang et al., 2024; Wuni et al., 2022; Yongdong et al., 2024)
R	Work–life balance	(C.-M. Alexe & Alexe, 2021; Popescu et al., 2023)
S	Digital skills	(C.-M. Alexe & Alexe, 2021; Margaritescu et al., 2020; Tiganoaia & Alexandru, 2023)
T	Performance appraisal	(Becker et al., 2023; Popescu et al., 2023)

Each respondent was also provided with a detailed description of each factor assessed to ensure clarity and consistency in the application of the methodology.

Educational level (A) refers to the level of academic qualification relevant to the job. This can refer to pre-university studies, bachelor's, master's, doctorate, completion of courses contributing to professional training, whether certified or not, or even possession of a driving licence (Oproiu & Lițoiu, 2019; Pirvu et al., 2024). Thus, this factor refers to the knowledge base formed by the completion of educational modules that include theoretical, practical or hybrid aspects. In addition, each sector has specific requirements and a characteristic minimum level needed to perform specific tasks (Barbu et al., 2023). Sectors such as IT, consulting, research and education, especially at university level, require higher education for most jobs (Popescu et al., 2023). However, in other sectors, such as retail, distribution, tourism or other activities, key functions—those that actually deliver

the service (C.-M. Alexe & Alexe, 2021)—do not require higher education; practical skills and relevant experience are sufficient. The concepts of over- and under-qualification are also taken into account in the recruitment process (Highfield, 2024). An employee is considered overqualified if the education level exceeds the requirements of the job. While this may appear to be an advantage, it can also expose the organisation to risks, such as demotivation, low retention rates and higher costs (Pirvu et al., 2024). On the other hand, under-qualification refers to the fact that the employee does not have the education level required to fulfil the requirements of the job, and this can lead to poor performance, stress and additional training costs (Pirvu et al., 2024).

Technical competencies (B) are the knowledge, skills and practical experience required to use specific tools, equipment, technologies or methods in a particular occupational field (Deepa et al., 2024). These competencies are measurable and objectively demonstrated, usually through certifications, concrete results or practical experience, as opposed to soft competencies, which are more subjective and difficult to quantify (Cordeiro et al., 2023). In many fields, technical skills are standardised to ensure consistent and efficient processes (Pennetta et al., 2023). This standardisation allows work to be transferred between different specialists, maintaining a consistent way of working and reducing the risks associated with individual differences (Istriteanu et al., 2024; Pennetta et al., 2023). By using common methods and techniques, organisations can improve collaboration, optimise processes and ensure a predictable and high-quality final result (Stochioiu & Stochioiu, 2021). These skills must be kept up to date as technologies and job requirements change rapidly (Dumitriu et al., 2019; Lincaru et al., 2023; Stanciu et al., 2024). Learning new methods and tools helps both to remain relevant in the labour market and to optimise work within the organisation (C.-M. Alexe & Alexe, 2021).

Experience in similar activities (C) refers to an individual's previous exposure to tasks, processes or responsibilities directly related to the job. This can be gained through previous jobs, internships and individual or collaborative projects. It contributes to the efficiency and adaptability of employees, reduces the time needed to adapt to a new role and provides a deeper understanding of the organisational context and job expectations (Davis et al., 2022). In certain situations, even a person with no direct experience in a particular area but who has worked in a team or together with someone with relevant experience in the past can bring added value through the knowledge and relationships they have built (Fleaca et al., 2023; M. S.-M. Lin & Lu, 2023). The recruitment process should therefore take into account both track record and the ability to absorb knowledge (Allal-Chérif et al., 2021).

The spirit of innovation (D) implies the ability to explore and apply new solutions, to go beyond the limits of traditional approaches and to find effective alternatives that are adapted to changing needs (C.-M. Alexe & Alexe, 2021). It requires, above all, enthusiasm for research and practical abilities, and the initiative to turn ideas into concrete action (C. M. Alexe, 2019; Cordeiro et al., 2023). A key part of innovation is being able to share ideas clearly and persuasively because they only make a real difference when they engage and inspire others (C.-M. Alexe & Alexe, 2021; Stanciu et al., 2024). Innovative thinking involves detailed analytical thinking and creativity, which are essential for assessing the feasibility and impact of innovative ideas, identifying the best solutions and adapting them to changes in the professional or technological context (Constantin et al., 2024; Deselnicu et al., 2023). This type of thinking is based on a deep understanding of the complex interactions between the variables involved (Estiri et al., 2021; Sun, 2021) and is essential both for generating innovative ideas and for putting them into practice in a sustainable and effective way. In addition, innovative thinking requires the ability to adapt rapidly to technological and organisational change, while fostering a working environment that encourages creativity

and continuous development, thus contributing to the progress of the whole organisation (James & Frank, 2015).

Flexibility and adaptability (E) are two fundamental characteristics that define the ability of an individual or an organisation to cope with rapid and unpredictable changes in the work environment (Z. Lin et al., 2020). They are necessary for survival in a dynamic economic and professional context and for long-term progress. Flexibility is the ability to transfer and reuse an existing set of knowledge and skills in a new occupational context. It does not imply the acquisition of completely different skills, but the redirection and effective application of those already developed to meet new requirements of a particular field. Flexibility allows an individual to make the transition to new areas of work without having to fundamentally rebuild their skills.

Adaptability, on the other hand, involves modifying and adapting existing skills to meet the specific needs of a changing environment. This process may involve simplifying, extending or restructuring existing skills to make them compatible with new conditions (C.-M. Alexe & Alexe, 2021). Unlike flexibility, which capitalises on experience in different contexts, adaptability involves continuous recalibration in response to changing occupational and technological demands.

Both concepts are good drivers for professional development, facilitating effective integration into dynamic environments and ensuring smooth transitions between different demands and work settings (C.-M. Alexe & Alexe, 2021; Popescu et al., 2023).

Personal motivation (F) refers to the set of factors that motivate an employee to actively engage and contribute to the achievement of the organisation's goals. It can be influenced by various aspects, such as the perceived role within a team (Kukhareva et al., 2024; Sulamo et al., 2021), personal and professional goals (Susanto et al., 2023) or external rewards offered by the organisation, such as pay, promotion or recognition (Ghosh et al., 2020). Motivation can be intrinsic, when employees find their work personally satisfying, or extrinsic, when they are stimulated by tangible rewards or recognition for their work. In a project specific to industrial organisations, personal motivation plays an important role in completing tasks within a certain time frame and to certain quality standards. Intrinsic motivation has a much stronger influence on employee performance because it comes from their own desire to complete the work for personal fulfilment and satisfaction (Ghosh et al., 2020; Popescu et al., 2023). To support and encourage this form of motivation, management must focus on creating an environment that supports employees' personal and professional development (James & Frank, 2015). One of the factors management should focus on is the organisational culture, which should promote values such as autonomy, continuous learning and trust (C. M. Alexe, 2019; Estiri et al., 2021; Schopmeyer et al., 2024; Wang et al., 2024). Clarity of roles and responsibilities is another important factor. It has been shown that when people understand exactly how their work contributes to the success of a project or the goals of the organisation (Ghosh et al., 2020; Susanto et al., 2023), they feel more engaged and motivated to put more passion into their work. Opportunities for professional development are also essential, as they give employees a sense of progress and personal fulfilment. If they feel supported in developing their skills, they will be more engaged in their work and see it as meaningful (Susanto et al., 2023).

Interest in the project (G) refers to the level of curiosity, involvement and attraction an employee has for a particular project or task. It is influenced by the relevance of the project to personal and professional goals (Ghosh et al., 2020), the nature of the activities involved, the impact of the work and the team culture. Interest may vary from project to project and may be temporary, depending on the attractiveness and challenge of the project (Pirvu et al., 2024; Wuni et al., 2022).

Time management skills (H) refer to a person's ability to plan, prioritise and allocate time to different tasks in order to maximise productivity and respect deadlines (Vulpes & Opran, 2022). Effective time management involves not only completing tasks on time but also maintaining a balance between quality and efficiency. It involves setting realistic goals, organising activities according to urgency and importance, reducing distractions and focusing on priority tasks (Aghamir, 2024). This factor remains relevant in both individual and team work. Employees with strong time management skills can handle their workloads more effectively, lower their stress levels and play a key role in the success of projects (Popescu et al., 2023).

Team dynamics—coordination (I) refers to how team members interact and how the various processes that influence their collaboration are managed, so this concept includes the coordination of activities, aspects such as the substitution of members, the rotation of roles and the synergy of individual competencies (C. M. Alexe, 2019; Pennetta et al., 2023). Substitution of team members can be a strategy to ensure a flexible structure that allows for quick and efficient transitions, ensuring that the functional role of the socio-technical structures is not interrupted (Cordeiro et al., 2023; Simion et al., 2021). Role rotation within the team is another strategy that defines the team dynamics. It involves shifting responsibilities between members, allowing them to learn new skills and broaden their professional experience (Owusu-Acheampong et al., 2024). In this way, the team becomes more adaptable and members can contribute more effectively in different contexts. The synergy of individual skills is another approach; the success of the team depends on how each member's skills and knowledge are combined to achieve the project's objectives (Cordeiro et al., 2023; Estiri et al., 2021). Coordinating these elements helps maximise team performance by creating an environment in which members can work together effectively, even in the face of uncertainty (C.-M. Alexe & Alexe, 2021; Pirvu et al., 2024).

Objectivity and impartiality (J) are essential principles in any analytical, decision-making or scientific endeavour to ensure a rigorous and fair evaluation of information. Objectivity implies a perception or judgement based solely on verifiable facts, data and realities, independent of personal opinions, preferences or experiences (Oproiu & Liţoiu, 2019; Roberts, 2024). An objective point of view accurately reflects reality, without subjective, emotional or ideological factors.

Impartiality implies a fair and unbiased approach in which all perspectives are equally considered, without favouring any (Roberts, 2024). These principles are essential in areas such as scientific research, business journalism and the law, where the accuracy and integrity of information influence public decisions and perceptions. Respect for objectivity and impartiality enhances credibility and contributes to a fair and balanced understanding of reality (Oproiu & Liţoiu, 2019; Roberts, 2024).

Negotiation skills (K) promote a dynamic process of interaction between two or more parties to reach optimal agreement by balancing divergent interests. From a scientific perspective, this process involves decision-making mechanisms, persuasion strategies and conflict management, and is influenced by cognitive, emotional and contextual factors (Chun et al., 2025; Estiri et al., 2021). Studies in social psychology (Gaffal & Padilla Gálvez, 2023) and behavioural economics (Kiessling et al., 2024) show that successful negotiation depends on the ability to build trust, analyse alternative scenarios and use techniques such as anchoring, give and take or framing. In a professional environment, effective negotiation is not just about gaining an immediate advantage but about developing sustainable relationships and mutually beneficial solutions (Chun et al., 2025).

Conflict management (L) is an important process in organisations to identify, address and resolve differences between employees in an effective and constructive way. It is not about avoiding conflict, but managing it in a way that prevents escalation and main-

tains a positive working environment (Băjenaru et al., 2025; Chun et al., 2025; Sun, 2021; Susanto et al., 2023). Proper conflict management can improve communication, foster collaboration and increase organisational productivity.

Conflict in the workplace can have a significant impact on performance and organisational climate. It can lead to low morale, reduced team effectiveness and even increased staff turnover. In addition, communication breakdowns caused by conflict can affect decision-making and the implementation of organisational strategies (Salih et al., 2022; Vrchota & Řehoř, 2021). In this context, early intervention and the use of effective conflict resolution techniques are essential to maintain organisational balance.

Several types of conflict can arise in an organisation, including personality conflicts, communication conflicts and resource conflicts (Dong & Qiu, 2024; James & Frank, 2015). Personality conflicts arise when employees have different working styles, values or beliefs (Susanto et al., 2023), which can lead to tensions. Communication conflicts are common and can be caused by different styles of expression, misinterpretation or lack of clarity in conveying information. Resource conflicts also arise when people compete for access to scarce resources such as time, money or equipment (Cristoiu et al., 2023).

Stakeholder relationships (M) are the set of interactions and processes by which an organisation manages and responds to the expectations of those who have a legitimate interest in its activities. These relationships are based on the principles of transparency, accountability and strategic engagement, and are designed to ensure consistency of decision-making and long-term sustainability (Gunduz & Almuajebh, 2020; Siokas et al., 2021). Effective stakeholder relationship management helps to optimise organisational processes and builds trust in decision-making structures (Estiri et al., 2021; Sun, 2021).

Transparency in communication (N) is a fundamental principle of decision-making and information processes, characterised by the accessibility, clarity and reliability of the information communicated. It involves eliminating ambiguity, ensuring an open flow of information and facilitating the correct understanding of messages by all recipients. Transparency in communication helps to build trust, optimise decision-making processes and reduce uncertainty, with a significant impact on organisational effectiveness and institutional relations (de la Puente Pacheco et al., 2024; Dong & Qiu, 2024; Vrchota & Řehoř, 2021).

Team climate of trust (O) is an organisational framework where team members build interpersonal relationships based on respect, transparency and mutual support. In such a climate, there is a high level of psychological safety that allows individuals to express their ideas (C. M. Alexe, 2019; Cordeiro et al., 2023), actively participate in the decision-making process and take intellectual risks without fear of being criticised or marginalised. This type of environment contributes to effective collaboration and improved organisational performance, as team members are more willing to share information, collaborate on problem-solving and contribute to innovation (de la Puente Pacheco et al., 2024; Vrchota & Řehoř, 2021). A climate of trust therefore ensures both emotional security and the development of supportive professional relationships, which are fundamental to the long-term success of the team (Romulo et al., 2022).

Engaging in lifelong learning (P) is a sustained commitment to developing professional skills throughout a career (Evans et al., 2022; Salih et al., 2022; Wang et al., 2024). It involves an active and deliberate approach to the acquisition of new competencies and the continuous updating of existing ones to respond to the demands of a dynamic and changing environment. An interest in lifelong learning reflects a progress-oriented mindset in which the individual or organisation takes responsibility for continuously improving performance and contributing to innovation (C.-M. Alexe & Alexe, 2021; Fleaca et al., 2023).

Strategic planning skills (Q) refer to an individual's competencies and abilities to think long term, analyse and structure complex information, which are essential in the

process of formulating organisational strategies (Barbu et al., 2023). These skills are not exclusively related to direct management experience or the completion of a formal strategic plan, but also include the ability to anticipate trends, assess available resources and make informed decisions that can influence the overall direction of an organisation (Abdullahi et al., 2022; M. S.-M. Lin & Lu, 2023; Nazemi et al., 2020; Salih et al., 2022). People with strategic planning skills are able to identify opportunities and risks, set clear objectives and develop appropriate solutions (Davis et al., 2022; Scarneo-Miller et al., 2024).

Work–life balance (R) is a challenging process of managing and allocating time and emotional resources efficiently and effectively so that individuals can successfully fulfil their work commitments without compromising their personal, social and family well-being (Popescu et al., 2023). This balance involves the conscious management of time and energy, recognising that over-commitment in one area can have a negative impact on other aspects of life (Pirvu et al., 2024).

Digital skills (S) refer to the set of knowledge, skills and abilities needed to navigate, analyse, create and distribute content in a digital environment using information technologies and the Internet. Digital skills include the ability to use various technological tools to address challenges or complete tasks in the digital environment (Crasoveanu et al., 2024; Tiganoaia & Alexandru, 2023).

Performance appraisal (T) is the process by which an employee's work is measured and analysed against set objectives to determine the extent to which they are being met. A key aspect of this process is the employee's perception of the appraisal, particularly in terms of the match between the feedback received and their expectations (Warin & Darmawan, 2024), often formed through self-assessment. This perception can have a significant impact on an employee's motivation and behaviour (Ghosh et al., 2020; Susanto et al., 2023; Warin & Darmawan, 2024), and alignment between self-assessment and external appraisal can support continuous development and performance improvement.

The key factors for evaluating human resources in the context of industrial projects have been identified and defined, extracted from the literature and validated by previous research. This solid theoretical basis allows the application of the DEMATEL method in the next step.

3. Materials and Methods

This is a qualitative research study based on the expertise of professionals with relevant experience, selecting respondents with management experience in industrial projects. The DEMATEL methodology specifically requires the use of 4 to 5 respondents to assess the interactions between factors (Estiri et al., 2021; Sun, 2021). The factors were evaluated based on the responses of five respondents holding management positions in industrial organisations, each with at least two years of experience, in order to assess the degree of mutual influence between them. The data were collected in January 2025. The questionnaire was structured as a relationship matrix containing 20 factors, and participants were asked to rate the influence of each pair of factors (400 arrangements) on a scale from 0 to 4, as follows:

- 0—no influence.
- 1—low influence.
- 2—moderate influence.
- 3—strong influence.
- 4—very strong influence.

These assessments of the interactions between factors form the basis for further analysis, allowing the identification of cause-and-effect relationships, which are essential for optimising human resource management in industrial projects.

The results of the analysis were obtained by applying a mathematical model, DEMATEL, which is used to assess the mutual influence between factors in the context of industrial organisations. In the first stage, the influence matrix Y (Table 1) was derived from the matrix A, which represents the mean values of the scores assigned to each factor. The relationship between the matrix Y and the matrix A is expressed by the following equation:

$$Y = A \cdot k \tag{1}$$

$$\text{Where } A = \begin{bmatrix} 0 & a_{12} & \dots & a_{1j} & \dots & a_{1n} \\ a_{21} & 0 & \dots & a_{2j} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{i1} & a_{i2} & \dots & a_{ij} & \dots & a_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nj} & \dots & 0 \end{bmatrix} \tag{2}$$

$$k = \frac{1}{max_{1 \le i \le n} \left(\sum_{j=1}^{n} a_{ij} \right)} \; (i, j = 1, 2, \dots, n) \tag{3}$$

where n is the number of factors analysed.

Having obtained the matrix Y, the next step is to derive the total influence matrix T. To calculate the matrix T, the inverse M_{INV} of the difference between the identity matrix Y and the direct matrix I (Table 2) must be calculated:

$$M_{INV} = (I - Y)^{-1} \tag{4}$$

The matrix T therefore represents the total influence matrix, which includes both direct and indirect effects between factors.

$$T = Y \cdot (I - A)^{-1} \tag{5}$$

The threshold for the α-factor assessment is determined using the following formula:

$$\alpha = \frac{\sum_{i=1}^{n} \sum_{i=1}^{n} [t_{ij}]}{N} \tag{6}$$

N is the total number of relationships or elements in the influence matrix, where $N = n^2$.

Once the total matrix has been calculated, the impact score D_i and the cause score R_j can be determined for each criterion.

The impact score D_i for each factor is calculated as the sum of its influence on all other factors:

$$D_i = \left[\sum_{j=1}^{n} t_{ij} \right]_{nx1} = [t_i]_{nx1'} \tag{7}$$

where $i \in \{1, 2, \dots, n\}$.

The causal score R_j for each factor is calculated as the sum of the influence of the factors on it:

$$R_j = \left[\sum_{j=1}^{n} t_{ij} \right]_{1xn} = [t_j]_{nx1'} \tag{8}$$

where $j \in \{1, 2, \dots, n\}$.

Table 2. Influence matrix.

Factor	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	0	0.065	0.062	0.04	0.036	0.04	0.033	0.029	0.033	0.04	0.04	0.04	0.047	0.029	0.044	0.058	0.062	0.029	0.044	0.051
B	0.051	0	0.062	0.047	0.044	0.036	0.062	0.04	0.047	0.029	0.036	0.018	0.036	0.011	0.044	0.051	0.047	0.018	0.044	0.047
C	0.036	0.058	0	0.044	0.062	0.036	0.058	0.051	0.065	0.047	0.051	0.033	0.047	0.033	0.058	0.055	0.051	0.022	0.033	0.055
D	0.029	0.055	0.047	0	0.055	0.051	0.047	0.022	0.033	0.022	0.022	0.011	0.033	0.022	0.047	0.055	0.04	0.018	0.044	0.04
E	0.051	0.044	0.062	0.044	0	0.044	0.047	0.062	0.065	0.044	0.062	0.055	0.055	0.04	0.051	0.044	0.044	0.051	0.036	0.04
F	0.065	0.055	0.055	0.047	0.04	0	0.069	0.051	0.047	0.033	0.04	0.029	0.051	0.029	0.047	0.069	0.044	0.044	0.047	0.047
G	0.04	0.044	0.047	0.029	0.033	0.058	0	0.04	0.062	0.04	0.044	0.033	0.062	0.04	0.051	0.065	0.047	0.025	0.04	0.051
H	0.044	0.036	0.04	0.018	0.055	0.033	0.033	0	0.036	0.015	0.029	0.025	0.036	0.018	0.025	0.047	0.047	0.058	0.022	0.033
I	0.036	0.047	0.055	0.029	0.044	0.036	0.055	0.044	0	0.044	0.044	0.051	0.047	0.051	0.065	0.055	0.044	0.025	0.04	0.051
J	0.007	0.018	0.022	0.007	0.036	0.036	0.04	0.033	0.058	0	0.044	0.065	0.058	0.055	0.069	0.022	0.029	0.029	0.011	0.051
K	0.025	0.029	0.033	0.018	0.029	0.015	0.018	0.025	0.036	0.044	0	0.069	0.069	0.047	0.047	0.025	0.033	0.033	0.011	0.033
L	0.011	0.015	0.022	0.011	0.047	0.018	0.018	0.029	0.069	0.058	0.062	0	0.069	0.055	0.065	0.022	0.022	0.036	0.011	0.036
M	0.029	0.029	0.047	0.018	0.051	0.025	0.055	0.029	0.047	0.036	0.069	0.062	0	0.055	0.058	0.036	0.044	0.025	0.015	0.036
N	0.011	0.015	0.036	0.007	0.033	0.015	0.015	0.036	0.065	0.044	0.055	0.062	0.062	0	0.069	0.025	0.036	0.036	0.015	0.04
O	0.022	0.047	0.051	0.029	0.051	0.051	0.055	0.025	0.073	0.069	0.044	0.069	0.062	0.055	0	0.058	0.036	0.036	0.025	0.04
P	0.073	0.065	0.069	0.044	0.04	0.055	0.058	0.033	0.051	0.047	0.036	0.033	0.047	0.025	0.047	0	0.04	0.036	0.062	0.051
Q	0.044	0.055	0.051	0.029	0.044	0.022	0.022	0.058	0.065	0.036	0.036	0.051	0.047	0.044	0.04	0.036	0	0.025	0.025	0.036
R	0.033	0.047	0.051	0.018	0.044	0.055	0.044	0.055	0.044	0.029	0.025	0.033	0.033	0.022	0.036	0.04	0.033	0	0.007	0.033
S	0.051	0.051	0.047	0.033	0.025	0.022	0.04	0.011	0.04	0.007	0.007	0.011	0.025	0.011	0.018	0.044	0.025	0.004	0	0.029
T	0.036	0.055	0.051	0.025	0.055	0.065	0.069	0.036	0.062	0.047	0.015	0.051	0.047	0.055	0.065	0.069	0.036	0.029	0.029	0

4. Results

The mutual influences between the factors were analysed using the DEMATEL methodology, leading to the construction of several matrices representing their interrelationships. Table 2 presents the influence matrix, which shows the direct influence scores between each pair of factors. This matrix is derived from the participants' responses, with each value representing the degree of influence of one factor on another.

Table 3 shows the inverse matrix, which is used to calculate the inverse of the direct influence matrix, allowing indirect influences between factors to be assessed. This matrix is used to calculate the total influence matrix, which includes both direct and indirect relationships.

Table 4 shows the overall influence matrix, which combines the direct and indirect influences between all factors, giving a complete picture of the interdependencies and the overall impact of each factor on the others. The calculated threshold for determining significant influences α is 0.181, and factors with influence values greater than or equal to this threshold have been highlighted in the matrix.

Figure 1 clearly illustrates the interactions between the factors, highlighting both the influences that each factor exerts on the others and the influences that it receives. In order to focus on a single factor for a clearer understanding, the arrows connecting the factors are rescaled, with greater thickness where the influence score is greater than or equal to the calculated threshold of 0.181, thus highlighting the significant links in the network.

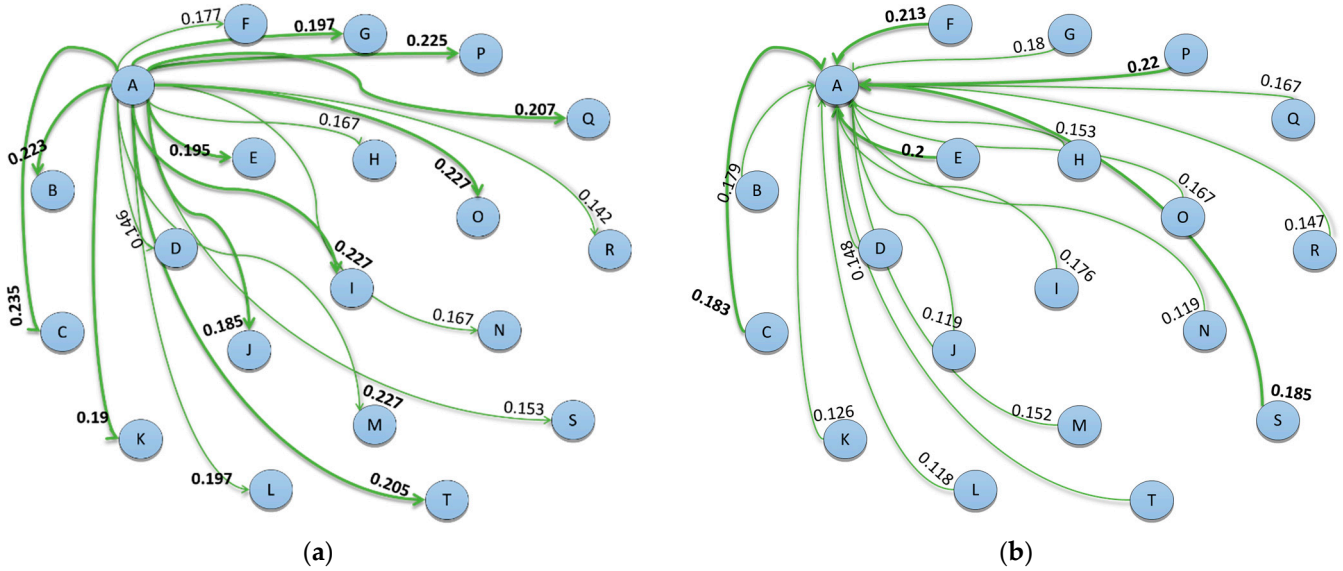


Figure 1. Influence relationships of factor A: (**a**) network of influence from factor A to the other factors; (**b**) network of influence on factor A from the other factors.

Table 5 presents the evaluation of the influence and causality of the factors, providing an assessment of the direct (D) and indirect (R) influence of each factor, as well as its total influence (D + R) and net influence (D–R). The values in the table represent the degree to which each factor influences others (D), is influenced by others (R) and the overall net influence it exerts within the system. The net influence value determines the dominant characteristic of each factor: if the net influence is positive, the factor is classified as a cause, whereas if the net influence is negative, the factor is classified as an effect.

Table 3. Inverse matrix.

Factor	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	1.136	0.223	0.235	0.146	0.195	0.177	0.197	0.167	0.227	0.185	0.19	0.197	0.227	0.167	0.227	0.225	0.207	0.142	0.153	0.205
B	0.179	1.154	0.227	0.148	0.194	0.169	0.216	0.17	0.23	0.167	0.178	0.168	0.207	0.143	0.217	0.212	0.187	0.126	0.149	0.194
C	0.183	0.23	1.192	0.158	0.233	0.187	0.235	0.2	0.275	0.205	0.214	0.206	0.244	0.184	0.258	0.238	0.211	0.147	0.153	0.223
D	0.148	0.192	0.199	1.094	0.19	0.17	0.189	0.142	0.2	0.147	0.151	0.147	0.188	0.14	0.204	0.2	0.167	0.116	0.14	0.174
E	0.2	0.221	0.256	0.161	1.181	0.198	0.229	0.215	0.281	0.207	0.23	0.231	0.257	0.196	0.257	0.232	0.209	0.178	0.159	0.214
F	0.213	0.23	0.247	0.164	0.215	1.155	0.247	0.202	0.259	0.193	0.205	0.202	0.249	0.181	0.249	0.254	0.207	0.168	0.169	0.218
G	0.18	0.208	0.228	0.139	0.198	0.2	1.172	0.183	0.261	0.191	0.2	0.198	0.248	0.184	0.241	0.239	0.199	0.144	0.154	0.211
H	0.153	0.165	0.182	0.105	0.181	0.144	0.164	1.114	0.192	0.132	0.15	0.152	0.181	0.129	0.173	0.182	0.165	0.148	0.111	0.158
I	0.176	0.212	0.235	0.139	0.209	0.18	0.223	0.187	1.205	0.196	0.201	0.216	0.237	0.195	0.257	0.229	0.197	0.145	0.154	0.212
J	0.119	0.15	0.168	0.095	0.171	0.152	0.176	0.149	0.222	1.127	0.173	0.201	0.212	0.174	0.225	0.164	0.152	0.127	0.102	0.18
K	0.126	0.149	0.166	0.098	0.153	0.121	0.144	0.132	0.188	0.158	1.121	0.192	0.209	0.156	0.191	0.154	0.146	0.121	0.094	0.153
L	0.118	0.142	0.164	0.096	0.177	0.131	0.152	0.143	0.227	0.178	0.186	1.137	0.218	0.171	0.217	0.158	0.142	0.131	0.098	0.163
M	0.152	0.175	0.208	0.116	0.198	0.153	0.203	0.158	0.229	0.175	0.21	0.211	1.173	0.185	0.23	0.192	0.18	0.133	0.116	0.181
N	0.119	0.143	0.177	0.092	0.164	0.127	0.148	0.149	0.224	0.165	0.179	0.195	0.211	1.119	0.22	0.162	0.156	0.131	0.102	0.166
O	0.167	0.217	0.239	0.143	0.223	0.199	0.231	0.177	0.282	0.227	0.21	0.241	0.259	0.206	1.205	0.239	0.196	0.16	0.145	0.209
P	0.22	0.241	0.261	0.162	0.215	0.207	0.238	0.185	0.263	0.206	0.202	0.206	0.246	0.178	0.25	1.19	0.204	0.16	0.183	0.222
Q	0.167	0.2	0.212	0.127	0.191	0.15	0.174	0.185	0.243	0.172	0.177	0.197	0.215	0.172	0.212	0.192	1.138	0.132	0.127	0.181
R	0.147	0.181	0.198	0.109	0.178	0.17	0.182	0.171	0.207	0.152	0.154	0.166	0.186	0.139	0.192	0.183	0.158	1.098	0.102	0.165
S	0.137	0.153	0.159	0.102	0.127	0.111	0.145	0.1	0.162	0.1	0.104	0.110	0.14	0.098	0.136	0.152	0.121	0.076	1.074	0.129
T	0.185	0.229	0.244	0.144	0.229	0.217	0.248	0.19	0.276	0.209	0.184	0.225	0.248	0.207	0.268	0.254	0.2	0.156	0.152	1.174

Table 4. Total influence matrix highlighting (*) factors with significant influence ($\alpha \geq 0.181$).

Factor	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	0.136	0.223 *	0.235 *	0.146	0.195 *	0.177	0.197 *	0.167	0.227 *	0.185 *	0.19 *	0.197 *	0.227 *	0.167	0.227 *	0.225 *	0.207 *	0.142	0.153	0.205 *
B	0.179	0.154	0.227 *	0.148	0.194 *	0.169	0.216 *	0.17	0.23 *	0.167	0.178	0.168	0.207 *	0.143	0.217 *	0.212 *	0.187 *	0.126	0.149	0.194 *
C	0.183 *	0.23	0.192 *	0.158	0.233 *	0.187 *	0.235 *	0.2 *	0.275 *	0.205 *	0.214 *	0.206 *	0.244 *	0.184 *	0.258 *	0.238 *	0.211 *	0.147	0.153	0.223 *
D	0.148	0.192 *	0.199 *	0.094	0.19 *	0.17	0.189 *	0.142	0.2 *	0.147	0.151	0.147	0.188 *	0.14	0.204 *	0.2 *	0.167	0.116	0.14	0.174
E	0.2 *	0.221 *	0.256 *	0.161	0.181 *	0.198 *	0.229 *	0.215 *	0.281 *	0.207 *	0.23 *	0.231 *	0.257 *	0.196 *	0.257 *	0.232 *	0.209 *	0.178	0.159	0.214 *
F	0.213 *	0.23	0.247 *	0.164	0.215 *	0.155	0.247 *	0.202 *	0.259 *	0.193 *	0.205 *	0.202 *	0.249 *	0.181 *	0.249 *	0.254 *	0.207 *	0.168	0.169	0.218 *
G	0.18	0.208 *	0.228 *	0.139	0.198 *	0.2 *	0.172	0.183 *	0.261 *	0.191 *	0.2 *	0.198 *	0.248 *	0.184 *	0.241 *	0.239 *	0.199 *	0.144	0.154	0.211 *
H	0.153	0.165	0.182 *	0.105	0.181 *	0.144	0.164	0.114	0.192	0.132	0.15	0.152	0.181 *	0.129	0.173	0.182 *	0.165	0.148	0.111	0.158
I	0.176	0.212 *	0.235 *	0.139	0.209 *	0.18	0.223 *	0.187 *	0.205 *	0.196 *	0.201 *	0.216 *	0.237 *	0.195 *	0.257 *	0.229 *	0.197 *	0.145	0.154	0.212 *
J	0.119	0.15	0.168	0.095	0.171	0.152	0.176	0.149	0.222 *	0.127	0.173	0.201 *	0.212 *	0.174	0.225 *	0.164	0.152	0.127	0.102	0.18
K	0.126	0.149	0.166	0.098	0.153	0.121	0.144	0.132	0.188 *	0.158	0.121	0.192 *	0.209 *	0.156	0.191 *	0.154	0.146	0.121	0.094	0.153
L	0.118	0.142	0.164	0.096	0.177	0.131	0.152	0.143	0.227 *	0.178	0.186 *	0.137	0.218 *	0.171	0.217 *	0.158	0.142	0.131	0.098	0.163
M	0.152	0.175	0.208 *	0.116	0.198 *	0.153	0.203 *	0.158	0.229 *	0.175	0.21	0.211 *	0.173	0.185 *	0.23 *	0.192 *	0.18	0.133	0.116	0.181 *
N	0.119	0.143	0.177	0.092	0.164	0.127	0.148	0.149	0.224 *	0.165	0.179	0.195 *	0.211 *	0.119	0.22 *	0.162	0.156	0.131	0.102	0.166
O	0.167	0.217 *	0.239 *	0.143	0.223 *	0.199 *	0.231 *	0.177	0.282 *	0.227 *	0.21 *	0.241 *	0.259 *	0.206 *	0.205 *	0.239 *	0.196 *	0.16	0.145	0.209 *
P	0.22 *	0.241 *	0.261 *	0.162	0.215 *	0.207 *	0.238 *	0.185 *	0.263 *	0.206 *	0.202 *	0.206 *	0.246 *	0.178	0.25 *	0.19	0.204 *	0.16	0.183 *	0.222 *
Q	0.167	0.2 *	0.212 *	0.127	0.191 *	0.15	0.174	0.185 *	0.243 *	0.172	0.177	0.197 *	0.215 *	0.172	0.212 *	0.192 *	0.138	0.132	0.127	0.181 *
R	0.147	0.181 *	0.198 *	0.109	0.178	0.17	0.182 *	0.171	0.207 *	0.152	0.154	0.166	0.186 *	0.139	0.192 *	0.183 *	0.158	0.098	0.102	0.165
S	0.137	0.153	0.159	0.102	0.127	0.111	0.145	0.1	0.162	0.1	0.104	0.11	0.14	0.098	0.136	0.152	0.121	0.076	0.074	0.129
T	0.185 *	0.229 *	0.244 *	0.144	0.229 *	0.217 *	0.248 *	0.19 *	0.276 *	0.209 *	0.184 *	0.225 *	0.248 *	0.207 *	0.268 *	0.254 *	0.2 *	0.156	0.152	0.174

Table 5. Assessment of the influence and causality of factors.

Factor	D	R	D + R	D–R	Dominant Characteristic
A	3.827	3.225	7.052	0.602	Cause
B	3.636	3.816	7.452	−0.18	Effect
C	4.177	4.197	8.374	−0.02	Effect
D	3.296	2.54	5.836	0.757	Cause
E	4.313	3.823	8.136	0.49	Cause
F	4.228	3.317	7.545	0.91	Cause
G	3.977	3.912	7.89	0.065	Cause
H	3.083	3.319	6.402	−0.236	Effect
I	4.006	4.65	8.656	−0.644	Effect
J	3.24	3.492	6.732	−0.251	Effect
K	2.971	3.618	6.589	−0.646	Effect
L	3.151	3.798	6.949	−0.648	Effect
M	3.579	4.354	7.933	−0.775	Effect
N	3.15	3.323	6.473	−0.174	Effect
O	4.173	4.429	8.602	−0.256	Effect
P	4.238	4.051	8.29	0.187	Cause
Q	3.562	3.541	7.103	0.022	Cause
R	3.238	2.74	5.978	0.498	Cause
S	2.434	2.639	5.072	−0.205	Effect
T	4.237	3.733	7.97	0.504	Cause

The results obtained highlight the importance of identifying the key influencing factors and support the decision-making process by providing a thorough understanding of the interactions and internal dynamics of the system under study.

The analysis of the factors influencing organisational performance, using the DEMATEL methodology, identified significant influences between various factors governing professional development and team dynamics. The results obtained through group standardisation show several interdependencies that provide an in-depth understanding of how these factors interact and influence each other. The analysis can therefore be deepened by detailing how each factor influences the others and by making theoretical and applied observations.

To make the analysis more structured and understand the bigger picture, the many relevant factors were grouped into five main categories: educational development, management skills, professional expertise, psychological factors, and team environment (Figure 2). This classification was adopted because these domains represent distinct yet interconnected aspects crucial to human resource effectiveness and overall organisational performance (Armstrong & Taylor, 2023). Educational development and professional expertise capture the essential knowledge and skills base of individuals, covering both foundational learning and practical, job-specific competence (Robbins & Judge, 2020). Management skills focus specifically on the competencies required for coordinating tasks, leading teams and navigating organisational complexities. Psychological factors address the individual's internal state, including motivation, adaptability, and well-being, which are recognised as significant drivers of behaviour and performance (Cropanzano et al., 2003). Finally, the team environment category contains the contextual and interpersonal dynamics within workgroups, such as communication, trust and objectivity, which heavily influence collaboration and collective output (Robbins & Judge, 2020). Grouping the factors this way makes it easier to analyse complex relationships, helping to identify patterns of influence across broader human resource areas rather than just looking at individual factor interactions. This hierarchical approach provides a clearer framework for interpreting the DEMATEL results and understanding the systemic impact of different human resource dimensions on each

other and on organisational outcomes. This allows for a deeper analysis of how each factor influences the others, leading to both theoretical insights and practical recommendations.

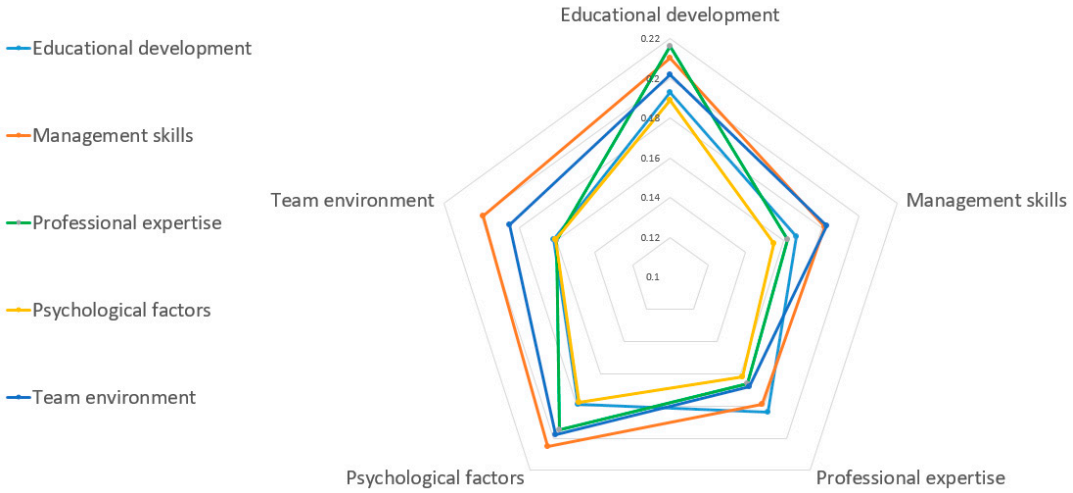


Figure 2. Radar chart of influence scores among core factors of human resource domains.

The factors of educational development are strongly influenced by professional expertise (0.216), suggesting a significant interdependence between theoretical knowledge and applied skills. In this sense, it can be observed that the educational process is not just an autonomous factor, but a continuous process of adaptation and enrichment of knowledge, significantly influenced by developments in the professional field. This influence underlines the need to integrate theory and practice in the lifelong learning of individuals in order to facilitate greater adaptability to the requirements of the labour market.

Complementarily, educational development is also influenced by psychological factors and management skills, with lower coefficients (0.179 and 0.167, respectively). These influences suggest that an individual's educational and psychological environment can shape the way in which knowledge is absorbed and applied, and that the interactions between these dimensions can lead to the formation of more complex and varied learning profiles.

Management skills are characterised by a significant influence of the team environment (coefficient 0.199), but also by an important influence of psychological factors (0.205) and educational development (0.167). These relationships suggest that effective managers must have both strong technical and pedagogical skills and advanced psychological skills that enable them to manage conflict, motivation and communication within teams. Success in management thus depends not only on technical knowledge, but also on the ability to interact and understand the psychological dynamics of teams.

An important aspect to emphasise is that management skills influence the team environment to a lesser extent than they are influenced by it. This suggests that the organisational and team environment plays a more important role in the development of managerial skills than team management itself. Thus, managers working in complex and dynamic work environments may develop superior skills that are influenced by the need to adapt and respond to the challenges of diverse teams.

Professional competence has a strong influence on factors related to pedagogical development (0.184) and its integration into daily practice. It is also influenced, but to a lesser extent, by psychological factors and the team environment, suggesting that professional factors are largely independent of the psychological and social context, at least in relation to the individual's applied knowledge and experience. This independence suggests that professional expertise is a fundamental and autonomous component in the formation of individuals and is continuously reinforced through practice. At the same time, professional

expertise subtly influences factors of educational development as well as management skills, suggesting that this type of expertise is essential for adapting to changing educational and professional needs. Expertise can also contribute to an organisational climate that supports continuous learning and improvement of educational processes.

Psychological factors strongly influence management skills (0.205) and team environment (0.198), highlighting the importance of mental state and emotional balance in work performance. These factors are also influenced by educational development (0.179) and professional expertise (0.195), suggesting that the psychological health of individuals is a product of their professional and educational experience, which has a significant impact on how they interact within the team and apply their skills. The relevant theoretical observation in this context is that the integration of psychological support in organisational settings can indirectly contribute to improving the performance of teams and individuals by enhancing their ability to cope with challenges and pressures. In this sense, a healthy psychological environment is essential to support long-term sustainable performance.

The team environment is significantly influenced by management skills (0.199) and psychological factors (0.198), suggesting that a positive and adaptive organisational climate, supported by effective management and an appropriate state of mind, plays a critical role in team performance. Furthermore, the influence of the team environment on leadership skills is relatively low (0.183), suggesting that organisational and psychological factors within teams have a greater impact on the formation of leadership skills than vice versa. In addition, observing the relationships between team environment and other factors, the profile of a leader working in a less homogeneous team can be outlined. This can be deduced from the fact that the team environment seems to influence rather than directly influence leadership skills. Thus, leaders working in such heterogenous teams might show greater flexibility in adapting their leadership style, and their success would depend to a considerable extent on the ability to create a balanced and coherent team environment.

The results obtained using the DEMATEL method suggest that, within organisations, the factors influencing the professional development and performance of teams are interrelated and cannot be analysed individually. It is also clear that the team environment plays a fundamental role in the success of the organisation and has a significant impact on management skills and overall performance.

This creates a profile of individuals working in a more diverse team environment, where the team's dynamics have a greater impact than managerial skills. It may reflect a tendency for managers to be more adaptable and flexible in the face of team diversity, indicating the need for ongoing training in interpersonal and leadership skills.

Therefore, in order to support organisational performance, it is essential that all key human resource factors—educational development, management skills, professional expertise, psychological factors and team environment—are integrated into a coherent system that is tailored to the needs of teams and the challenges of the professional environment.

5. Discussion

In order to validate and contextualise the results obtained in this study, a comparison was made with similar studies that analysed HR factors using multi-criteria decision-making methods.

The study by Estiri et al. (2021), conducted in the banking sector, used the DEMATEL method to explore causal relationships between human resource factors. Four elements in their model correspond conceptually to the factors in our analysis. While some similarities were observed, such as the causal role of personal motivation and team dynamics, some differences emerged, particularly in the causal ranking of technical skills and project interest. This divergence can be attributed to sectoral differences, as banking institutions

and industrial organisations operate under different operational dynamics and staffing structures. The variation highlights the importance of contextualising decision-making patterns in sector-specific environments.

The following outlines the key points of convergence and divergence between our study and that of Estiri et al. (2021) are as follows:

- Both studies used the DEMATEL methodology to assess causal relationships among HR factors.
- Both extracted the evaluated factors from the existing literature, ensuring a theoretically grounded framework.
- Their model included only 7 factors, resulting in 49 influence relationships, while ours included 20 factors and analysed a network of 400 influence relationships, offering a significantly more comprehensive view.
- No significance threshold (α) was calculated or applied in their study, whereas our model includes a systematically computed threshold to filter meaningful influences.
- Their research was applied to the banking sector, whereas ours focuses on industrial organisations, which differ in structure, dynamics and workforce characteristics.

In the study by Isac and Waqar (2016), which focused on industrial organisations, the authors examined the role of personal motivation and its impact on several organisational dimensions, such as communication and cooperation, working conditions, events and campaigns, professional development, management/leadership style and relationship with line managers. Their results strongly support the conclusion that personal motivation acts as a causal determinant, which is consistent with our findings, where personal motivation was one of the top-ranked causal elements. This alignment reinforces the robustness of our model and confirms the critical importance of intrinsic motivators in modelling human resource efficiency in industrial contexts.

A relevant point of comparison can be identified in the study conducted by Sang-Bing Tsai (2018), which analysed the key criteria influencing job satisfaction among research and development personnel. In this study, four factors were highlighted as essential, compensation, promotion, supervisors, and job nature, all categorised within the "high-relation, high-prominence" quadrant. These were considered core causal factors, significantly influencing the other criteria, and the author emphasises that improving them could lead to a systemic effect on overall job satisfaction. The results obtained in our study—although applied in a different industrial context and using a more comprehensive DEMATEL methodological approach—support this general idea of key causal factors with major impact. In particular, "performance appraisal", "interest in the project" and "personal motivation" emerge as critical drivers in our model, conceptually comparable to "compensation" and "promotion" in Tsai's framework in terms of their effect on employee engagement and satisfaction. Moreover, "work–life balance" and "flexibility and adaptability" are among the important causal factors in our analysis, aspects that may correspond to the perceived quality of job nature in Tsai's study. It is noteworthy that both studies outline the idea that employee satisfaction and performance cannot be improved solely through secondary environmental factors (e.g., fringe benefits or co-worker relations), but require strategic intervention on a core set of structural factors that directly impact motivation, professional status and perception of job meaning.

The study conducted by Sayyadi Tooranloo et al. (2017) proposes an integrated fuzzy Analytic Hierarchy Process (AHP) and interval type 2 fuzzy DEMATEL model for the assessment of factors influencing sustainable implementation of human resource management. Both studies use the DEMATEL method to analyse causal relationships and categorise factors into cause and effect types. However, the methodology used in this paper is based on the classic DEMATEL, supported by a Delphi analysis with industry experts,

without the integration of AHP weights. Both papers identify psychological factors as primary causes of organisational effectiveness. In our study, motivation, innovativeness and work–life balance are among the most influential causal factors. These correspond directly to indicators such as psychological needs satisfaction and well-being, which were identified as "effective indicators" in the fuzzy model of the comparative study. This correlation strengthens the validity of the findings, indicating that psychological aspects play a crucial role in both industrial and sustainable contexts. With regard to the components of social justice and collective responsibility, present in the comparative study as indicators of social sustainability, these dimensions are found in our research in the form of the factors of objectivity and impartiality, categorised as reactive factors. Thus, although both studies recognise the importance of these elements, their positioning is different: in the fuzzy study, they appear as influential factors in support of social sustainability, whereas in the industrial context of our study, they are more likely to be the result of other influences.

Our study, which focuses on the intelligent allocation of human resources in industrial organisations, can be contrasted with the study of Chatzifoti et al. (2025), who propose an integrated fuzzy AHP and interval type 2 fuzzy DEMATEL model for prioritisation of factors affecting the sustainable implementation of human resource management. Both studies focus on the causal relationships between factors and their categorisation into cause–effect categories. In our case, the use of classical DEMATEL, applied to a sample of experienced managers in industrial projects, allowed the identification of strong causal factors such as personal motivation, innovativeness, educational level, work–life balance and adaptability, which decisively influence other relevant competencies. Similarly, the comparative study suggests a categorisation of sustainability factors in terms of causality, highlighting that the environmental dimension and certain social indicators—such as social infrastructure or access to employment opportunities—are active factors, while other elements, such as social responsibility or psychological needs, are effects. Therefore, there is convergence in the conceptual structuring of networks of influence, although the purpose and context of application are different. Moreover, we can observe an interesting overlap between some of the findings: for example, in both studies, psychological factors—motivation, emotional balance or satisfaction of individual needs—are perceived as essential in determining organisational behaviour, but are rather reactive, i.e., dependent on other enabling conditions.

A second line of comparison can be drawn with the study by Chatzifoti et al. (2025), which proposes the integration of external knowledge into machine learning models using techniques such as KEQA (Knowledge Engineering Quality Assurance) and KELM (Knowledge-Enhanced Learning Machine). Although the aim is technological in nature, aimed at improving performance in NLP (Natural Language Processing) tasks, there is an important methodological parallel. Just as we used expert knowledge to build a network of 400 causal relationships between human factors, their study uses semantic graphs and external knowledge representations to strengthen the decision consistency of algorithms. Thus, both papers validate the idea that the performance of a system—whether human or automated—depends on how its constituent elements are correlated and contextualised. In conclusion, although the differences in methodology and domain are obvious, the studies analysed provide relevant points of contact both conceptually and in interpreting the causality of decision factors.

These comparisons highlight the industry-specific nature of the causal relationships between HR attributes, while demonstrating the transferability and validity of key influencers, such as motivation, across different organisational settings.

This study provides a valuable perspective on the links between human resource attributes in industrial projects, as it addresses a network of 400 influence relationships,

which represents a much more comprehensive perspective than previous research in this area. This study may also be applicable to other fields by applying the questionnaire resulting from the literature review. However, as this is qualitative research, meaning that the results depend on the expertise of the respondents, it must be completed by managers with experience in the industry or field to which this research is to be adapted. This is because the analysis relies heavily on the subjective judgements of the selected experts, whose perspectives may be influenced by their personal professional experiences, sector-specific norms or regional and cultural contexts.

In addition, the model developed in this study is based on a set of 20 human resource factors. Although these factors have been identified through a rigorous literature review, it is possible that they do not cover all relevant dimensions applicable in other organisational contexts or industries. Therefore, the proposed framework may not be directly transferable to sectors operating under different functional dynamics, but should be complemented with specific key factors.

Furthermore, we live in increasingly dynamic times and contexts are changing at an alarming rate; it is recommended that this study be repeated whenever deemed necessary at the strategic management level. Given these aspects, the results of this research should be interpreted with caution when applied to other organisational contexts.

6. Conclusions

This study investigated the complex interrelationships among human resource attributes in industrial organisations, using the DEMATEL methodology to optimise labour allocation in industrial projects. The findings emphasise the importance of a structured and systematic approach to human resource management, demonstrating that labour effectiveness is influenced by a combination of skills, experience, motivation and adaptability.

The study highlights the necessity for organisations to adopt a holistic perspective in human resource planning, ensuring that recruitment, training and development strategies align with both individual competencies and organisational goals. Effective team coordination, transparent communication and continuous learning were identified as fundamental elements in fostering an adaptable and high-performing workforce.

Furthermore, the research emphasises the dynamic nature of human resource factors and their reciprocal influence on organisational efficiency. Well-managed labour not only enhances individual performance but also contributes to overall project success. This suggests that organisations should implement evidence-based policies that facilitate skill enhancement, engagement and strategic decision-making.

Understanding these complex relationships helps managers figure out the right actions to boost team performance and reach project goals. By focusing on the key factors that drive success and creating a work environment that encourages growth, organisations can make better use of their human resources and greatly improve the chances of project success. This strategic approach, based on a rigorous analysis of the interrelationships between human factors, is an essential component of modern human resource management in the dynamic and competitive context of industrial organisations.

Although this study makes a relevant methodological contribution, some limitations should be mentioned. Firstly, the data collection was based on managers' self-assessments, which may introduce subjectivity bias in the perception and evaluation of competencies. Secondly, the set of competencies analysed was derived from the existing literature and practical experience, with the possibility that other competencies of specific relevance were not included in the conceptual model. Furthermore, it is important to mention that the external validity of the results may be influenced by the specificities of the organisational context of each industrial company.

Further research could explore the applicability of the DEMATEL methodology in a wider range of organisational contexts, including different industries and organisations of different sizes, in order to assess the robustness and applicability of the model. Another important direction is exploring how putting the obtained results into practice affects key project performance indicators. Extending the model by integrating other relevant variables, such as technological, economic or organisational culture-specific factors, could enrich the predictive capacity of the analysis. It is also proposed to deepen the dynamic analysis of the interrelationships between the identified competencies, using longitudinal studies to assess the evolution of these links over time and according to project characteristics. Another opportunity of research could be to integrate the DEMATEL methodology with other multi-criteria analysis tools or human resource management techniques in order to develop an integrated and optimised decision-making framework.

In conclusion, this study provides a comprehensive framework for understanding and optimising human resource allocation in the industrial environment. By recognising the interdependencies among labour attributes, organisations can create sustainable management practices that improve productivity and long-term success. Future research should explore how technological advancements and an evolving work environment further shape the effectiveness of human resource strategies.

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Institutional Review Board Statement: Authors have completed the ethical self-assessment form for our research project. This form serves to preliminarily evaluate whether the study requires further review by the ethics committee. Based on the responses provided in the self-assessment—which reflect the non-invasive nature of the research, the absence of any collection of personally identifiable data, and the fact that participants are properly informed and provide consent—it has been determined that a formal evaluation by the ethics committee is not required. According to our institution's procedure, this outcome indicates that the study falls into a category that does not require additional ethical approval, as it poses no risks to participants and does not involve ethically sensitive aspects.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding author up-on reasonable request.

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