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Critical success factors for rail infrastructure joint ventures

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Abstract
Due to their myriad socioeconomic and environmental benefits, Joint Ventures (JVs) between construction contractors are considered a highly effective commercial strategy for delivering construction projects. This is especially true in the rail infrastructure industry. While rail infrastructure JVs (RIJVs) between several contractors may not always run smoothly, there have also been cases of successful implementation; nevertheless, the factors contributing to their success have not been comprehensively explored. It is crucial to thoroughly understand the critical success factors (CSFs) for RIJVs, as their success depends on the combination of various key factors during their implementation. This study aims to evaluate the CSFs for RIJVs. Through a comprehensive literature review, 20 CSFs for RIJVs were identified, and an expert survey was conducted with 40 UK-based RIJV professionals. The data were analysed using the relative importance index and Spearman's rank correlation analysis. The top five perceived CSFs were communication, compatibility of partner objectives, suitable JV partner selection, trust, and effective planning. This suggests the level of importance attached to these CSFs by the professionals working in and managing RIJVs. Spearman's rank correlation analysis revealed significant interdependencies among CSFs, such as the combination of trust with communication and the intent to learn with the level of participation and involvement, suggesting that these CSFs often go hand in hand. Further analysis of challenges encountered on RIJVs revealed four key themes: information management and IT systems integration, alignment, congruency and synergy, inter-organisational dynamics, and strategic management. Solutions proposed for these challenges also fell into four primary themes: strategic management and leadership, collaboration and communication, risk management and conflict resolution, and operational efficiency and resource optimisation. The findings showed a comprehensive evaluation of CSFs for RIJVs, highlighting pathways to effective JV execution. This study makes a valuable contribution to the existing body of knowledge on RIJV by analysing the CSFs. It also offers practical insights that can enhance the successful implementation of RIJV projects and provide guidance for top team managers in allocating strategic resources to key areas.

1 Introduction

The forthcoming investment of over £44 billion in the UK's rail infrastructure development from April 2024 through the subsequent five years heralds a proliferation of extensive rail construction projects [1]. This substantial financial commitment has opened a myriad of opportunities for contractors to engage in competitive bidding. As a result of the large scale of these projects and the substantial resources required, as well as the inherent risks and the need for extensive expertise, joint ventures (JVs) are often considered as a viable commercial strategy. The JV is considered as an effective mechanism to adeptly navigate the complex and intricate challenges intrinsic to such large-scale

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projects. JVs can be defined as a lasting collaboration between two or more entities, which can be companies or individuals, where at least one of the participants is an active entity that seeks to expand its operations by engaging in a new profit driven business venture [2]. This definition underscores the essence of such partnerships in the rail sector: longevity, mutual engagement, and a profit-focus. Particularly for rail infrastructure projects, these alliances are crucial to amalgamate resources, expertise, and risk-sharing—actions that are critical for tackling the large-scale, convoluted and often high-cost nature of these ventures.

JVs between contracting companies have become an increasingly common strategy in the construction industry given their ability to provide a wealth of economic resource, a variety of skills and an expansive knowledge base to win work on large scale projects, such as extensive rail infrastructure projects, and expertly deliver [3]. Rail infrastructure developments in the UK have frequently embraced the use of JVs, with one notable example being the Elizabeth Line construction, delivered by the JVs: BFK (BAM, Ferrovial and Kier), BBMV (Balfour Beatty, Morgan Sindall and VINCI) and many others [4]. High Speed 2, a landmark rail project in the UK, is another prominent example of a project heavily relying on deliverance through JVs such as Align (Bouygues Travaux Publics, VolkerFitzpatrick and Sir Robert McAlpine), SCS (Skanska, Costain and STRABAG AG) and others [5]. The use of JVs where several large-scale contractors have come together to deliver high-profile projects underlines the importance of maximising their output and understanding what makes a JV successful.

The success of JVs in such projects is often influenced by a multitude of CSFs—many of which have been explored to an extent under existing literature, especially in the context of International Joint Ventures (IJVs), for various categories of projects; e.g. [6, 7]. Many of these explored factors under existing literature, such as trust between the JV partners, management control and objective compatibility [6], can be transcribed to projects of different natures, such as mega housing developments, highway systems as well as rail infrastructure projects. However, rail infrastructure projects can also bring about their own separate barriers to success given their complicated nature. This is due to the involvement of multifaceted stakeholders, financial considerations with regards to funding as well as technical challenges. Zhou et al. [8] elaborates on how projects in the rail infrastructure industry demand complex elements to be considered such as track equipment, infrastructure, energy and signalling systems, requiring extensive collaborative efforts from varied expertise—a strong characteristic of JVs, as a collective benefit can be obtained through each partner's complimentary resources and expertise. With regards to the specific financial constraints and stakeholder involvement brought about to these projects, HS2 is the quintessential example of this with the government decision to disband Phase 2, Birmingham to Manchester, following continued public backlash and soaring costs [9]. Since most rail infrastructure developments tend to be public projects, similar barriers to success would be expected on these projects. Additionally, rail projects tend to differ significantly from other sectors due to their logistical and regulatory aspects. Therefore, whilst a great amount of literature on JV success factors currently exists, this largely relates to construction projects in a general context and does not consider the minutia of project specific differences that can impact factors relating to JV success. This paper will extensively explore the context of JVs between several constructors to deliver large scale rail infrastructure projects.

This study aims to identify and analyse the key CSFs for successful RIJVs and identify the challenges in achieving these CSFs. By examining the CSFs explicitly in the context of rail infrastructure JVs (RIJVs), a nuanced understanding of challenges presented by this industry can be understood. The specificity of the research will enhance the relevance of findings, enabling the development of tailored approaches to optimise RIJV performance. Consequently, a generalised study can overlook specific nuances which would lead to less optimal findings and recommendations for those involved in RIJVs. Addressing this niche demand, this study aims to dissect and understand the Critical Success Factors (CSFs) that are perceived to underpin JVs in the context of rail infrastructure projects, shedding light on their role in the efficient and successful execution of complex rail infrastructure developments.

2 Literature review

The purpose of this literature review is to provide preliminary research on JVs in both a general and construction context, the importance of CSFs and the most common CSFs identified from existing literature to be further analysed, providing a foundation for research pertaining to the CSFs of RIJVs.

2.1 Joint ventures

The phrase "strategic alliance" had been coined with reference to joint ventures to further elaborate on their definition, following the development of a wide variety of inter-firm cooperative agreements since the early 1980s [10, 11]. A strategic alliance can be further defined as a network of agreements where two or more entities join forces, combining their resources and coordinating their efforts to achieve a shared objective [12].

Despite JVs being historically popular in some industries such as off-shore oil exploration and jet engines [13], their emerging popularity in construction is a relatively recent phenomena [14]. However, since the 1980s [3], JVs have become more desirable commercial structures for many contractors due to their various benefits for high-profile projects, a few of which are increased financial stability, favourable risk apportionment and greater resource availability [15]. Norwood and Mansfield [16] conducted further research into the advantages of using JVs in construction, discovering the following: improved company capability in terms of size and scope of work undertaken, broadening of company expertise, cross fertilisation of ideas from other companies, ability to select staff internally for the JV as opposed to external recruitment, reducing the impact of new arrival company adaptation.

Although JVs can present some drawbacks—Orzohon et al. [17] discussed the use of JVs in construction in the form of IJVs, which differ to conventional JVs as these possess at least one partner with its headquarters outside the JV's country of operation [18]. The presence of certain drawbacks, including difficulty in management due to differing managerial systems, philosophies and values, as well as the potential blurred lines between partners who could view one another as competitors as well as collaborators have been suggested [19, 20].

2.2 Rail infrastructure projects

Large scale rail infrastructure projects can be defined as Mega rail projects that "require extensive budget, planning, construction periods, and expertise in numerous areas", with the purpose of enabling development, achieved by integrating or accelerating the economic growth in a specific area [21]. Zhao et al. [22] and Hwang et al. [23] have carried out extensive research pertaining to the risk associated with RIJVs, revealing risks such as "disagreement on some conditions in contract", "unclear division of responsibilities and risks" and "differences in culture and working styles" as the most critical risks. These ideas can be somewhat extrapolated and transcribed in the context of CSFs for RIJVs, however research into the specific application and evaluation of CSFs for RIJVs appears to be relatively sparse, further highlighting the need the specific research into this area.

2.3 Critical success factors

Critical success factors (CSFs) can be defined as "The limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department or organisation" [24]. This definition is further condensed by Freund to the few important domains where "things must go right" to allow the enterprise to prosper. In the context of construction, Adnan and Morledge [25] indicate that CSFs are those essential areas of activity where achieving positive outcomes is crucial for a manager to effectively meet their goals, hence also serving as a vital component of measuring JV success. There is a general across examined literature that a specific combination of the CSFs will influence the project success of JVs [26].

Table 1 demonstrates a total of twenty identified factors, along with their corresponding sources to show the frequency of each factor across existing literature. The five underlined CSFs in Table 1 are those that have been selected to be further analysed in this literature review given their relative frequency in existing literature and relevance to RIJVs.

Out of the 20 factors identified from literature, 5 factors have been selected for further discussion in the next subsection. These five CSFs of; selection of a suitable partner, compatibility of objectives, trust, management control systems, and a clear statement of JV agreements have been qualitatively identified based on the number of times they have appeared in the literature sources reviewed. These CSFs have been prominently featured in numerous scholarly articles and are considered to have significant applicability to RIJVs. The subsequent sections will delve deeper into these factors, exploring their implications and potential impact on the success of JVs as reflected in the existing literature.

Table 1 Identified CSFs of JVs in construction across existing literature

No.	Critical success factor	References
1	*Selection of a suitable partner*	[3, 6, 26–30]
2	Control of the majority ownership of the capital	[6, 29, 31]
3	*Compatibility of partner's objectives*	[26, 28–38]
4	*Clear statement of JV agreement*	[3, 29, 30, 36, 38]
5	Obtaining enough information about potential partners before negotiation	[29]
6	Cultural differences	[3, 30, 38]
7	*Management control*	[3, 18, 26, 28, 30, 31, 36, 38–42]
8	Communication	[3, 30, 31, 36, 40]
9	*Trust*	[3, 6, 26, 28, 30, 31, 37, 43–45]
10	Intent to learn	[37]
11	Level of participation and involvement	[26, 37, 41]
12	Lack of expertise and confidence	[41]
13	Conflict amongst partners	[31, 33, 37, 38, 40, 41]
14	Lack of effective planning	[41]
15	Complementary technical skills and resources	[26, 31]
16	Size of firms	[3, 30, 36]
17	Partner's experience	[26, 30, 31]
18	Financial stability of partners	[36, 46, 47]
19	Effective human resource management	[6, 31, 36]
20	Profit focus of JV	[29, 30]

2.4 Frequently occurring CSFs in existing literature

2.4.1 Selection of a suitable partner

Studies by Gale and Luo [29] highlight this as the most crucial factor for JV success, particularly during formation. Gale and Luo [29] liken a JV to a marriage, emphasising the need for a committed and steadfast relationship, necessitating a careful evaluation of the partner. Previous working experience is another crucial aspect of partner selection [6], as it enhances the likelihood of mutual agreement during conflicts, thereby reducing intra-organisational tensions.

2.4.2 Compatibility of objectives

Famakin et al. [36] found that partners ranked this as the most crucial factor for JV success, especially during the formation stage. Harmonising individual partners' objectives is essential for ensuring mutual understanding before contract agreement [36]. While objectives may evolve throughout the project lifecycle, they must remain aligned to reduce internal conflicts. Kwok et al. [28] corroborate the importance of mutually acceptable objectives, though achieving this is often challenging due to differing objectives [32]. Mohamed [35] emphasises the need to address these objectives during the formation stage by identifying common interests to achieve collective goals. Kottolli [34] warns that differing objectives can lead to conflicts of interest, particularly during high uncertainty in the JV's early stages.

2.4.3 Trust

Trust between JV partners is a frequently mentioned CSF in literature. Trust develops through successful business execution and fairness [48]. Lu et al. [40] highlight trust's role in maintaining good business relationships, yielding benefits like improved stakeholder satisfaction, potential future business opportunities, and consistent partner objectives [26, 40]. Trust is intertwined with objective compatibility [28, 31, 36] as it fosters collaboration toward mutually beneficial objectives. Girmscheid and Brockmann [45] provide an in-depth examination of trust in JVs, presenting a trust model

comprising the trust process, object of trust, and consequences of trust. Their analysis shows trust must be established from the outset and reinforced through repeated interactions. They emphasise history-based trust, developed from past projects, as crucial for building face-to-face trust over time.

2.4.4 Management control

MC is the process where one party "*influences the behaviour and outcome of another party to varying degrees through power, bureaucracy, and/or informal mechanisms*" [18]. It involves the scope of control, extent of control, and procedures used to achieve control. Geringer and Herbert [18] identified three key MC characteristics: scope over what each parent has control over, extent of this control, and procedures. Killing [19] noted that a common decision-making method in IJVs is one partner having dominant control alongside shared management. However, shared responsibility often leads to increased partner contributions and higher returns on investment [39].

2.4.5 Clear statement of JV agreement

The JV agreement is a CSF outlining the parties involved, profit/loss sharing, management, decision-making processes, and dispute resolution [18]. Famakin et al. [36] emphasise its importance at the formation stage for mutual acknowledgment of objectives. Gale and Luo [29] rank the JV agreement as the second most important success factor, defining each party's rights, responsibilities, and profit distribution to prevent internal conflicts. Dymsza [49] notes that conflicts often arise from ambiguous contractual clauses, stressing the need for clear and precise language to define rights, responsibilities, and obligations, thereby avoiding disputes over payments, project specifics, and other collaboration-related factors.

To conclude, this literature review has successfully established comprehensive groundwork for further investigation into the CSFs pertinent to RIJVs. By systematically identifying twenty CSFs recurrent in the existing body of literature, and further examining five predominant factors—selection of a suitable partner, compatibility of objectives, trust, management control systems, and a clear statement of JV agreements—this review underscores their profound impact on JV outcomes and will be contrasted to those CSFs discovered as important to RIJVs through upcoming research.

3 Research method

3.1 Data collection

A questionnaire of two parts, the first being quantitative and second qualitative, was used to answer the research questions raised for this research. This integrated approach of research was adopted as "*blending qualitative and quantitative methods of research can produce a final product that can highlight the significant contributions of both*" [50]. Therefore, the benefits of both research types can be employed as the quantitative data provides broad and generalised data through statistical analysis, yet qualitative data can offer greater depth and contextual insight [51, 52].

Combining quantitative and qualitative analysis was thought as beneficial for evaluating critical success factors in RIJVs. Quantitative data offers statistical insights into patterns and trends, while qualitative research provides depth by capturing detailed experiences and perceptions [53]. Data triangulation also enhances credibility, allowing cross-validation where qualitative insights explain quantitative results, leading to robust conclusions [52, 54].

3.2 Sampling method

This research used non-probability sampling, defined as using "*non-randomised methods to draw the sample*" [55]. Non-probability sampling includes quota, purposive, self-selection, and snowball sampling [56]. Snowball sampling was chosen, recruiting future participants through existing ones [57]. This method is suitable for hard-to-recruit populations, like construction professionals with RIJV experience. However, it cannot calculate sampling error or determine confidence in interpretation [56], as well as the inability to accurately calculate a response rate. The sampling method however allows responses to be obtained from those who are relevant and able to make an informed and valid contribution. The sample for this questionnaire includes construction professionals (project managers, commercial managers, quantity surveyors, engineers, planners) with RIJV experience, representing the Client, Contractor, or Consultant. Including diverse professional backgrounds, not limited to commercial roles, enhances data quality. Respondents from various fields (project management, commercial, engineering,

etc.) provide varied perspectives on challenges and solutions in achieving CSFs, enriching the qualitative data. Respondents were selected as those working on two specific RIJVs and the questionnaire remained live for 14 days (19/02/2024 – 04/03/2024). 40 fully completed questionnaires were received and used for the analysis.

3.3 Data analysis

Questionnaire findings were analysed using both quantitative and qualitative analysis techniques.

3.3.1 Quantitative analysis

3.3.1.1 Weighted mean and RII Respondents were asked to rank 1–5 the importance of 20 CSFs for construction JVs, identified from existing literature, in the context of RIJVs using a five-point Likert scale, ranging from 'Unimportant' to 'Utmost importance' as displayed in Fig. 1. Likert scales have been employed as they are flexible, allow results to be easily analysed and are also simple for respondents to complete [58].

This Likert scale deviates from the usual format, e.g., 'very unimportant' to 'very important' [59], as all CSFs are inherently 'important'. Given their critical nature, most CSFs would typically rate at least a 4 using the conventional scale. The scale is adjusted to identify the most crucial CSFs for RIJVs, reflecting their significant impact on project success.

For each CSF, the weighted mean was calculated by multiplying each Likert scale value by the number of responses it received, summing these products, and then dividing by the total number of responses, displayed by the below formula.

$$Wighted\ Mean = \frac{\Sigma WX}{\Sigma W}$$

(Statistics How To, 2024) [60].

where:

$$\Sigma = \text{summation} w = \text{the weights} x = \text{the value}$$

This method effectively gave more weight to responses indicating higher importance, providing a nuanced measure of each CSF's perceived significance. The resulting weighted means, therefore, reflected a prioritised view of CSFs in the context of RIJVs.

Relative importance index (RII), a non-parametric method, was utilised in ranking the responses extracted from the Likert scale rating of the 20 CSFs due to the non-parametric nature of Likert scales which produce ordinal data [61]. RII compares the significance of elements [62], effectively prioritising factors based on importance. This method has been successfully used to identify and rank elements by significance [63, 64], providing a structured approach to understanding their relative weights.

RII is calculated as:

$$RII = \frac{\Sigma W}{AXN}$$

where:

W = weight given to each CSF by respondents and ranges from 1 to 5.

A = the highest weight = 5 N = the total number of respondents = 40.

In the results, 5 main categories for each CSF were displayed: number of responses indicating 'utmost importance', number of responses indicating 'unimportant', weighted average, RII and ranking based on RII.

Results of RII fell between 0 and 1, and CSFs were ranked based on their RII value from highest to lowest. Additionally, the number of responses indicating 'utmost importance (5)', number of responses indicating 'unimportant (1)' and weighted mean were also provided for each CSF in the results table to allow a broad spectrum of comparison for determining the most important CSFs as well as CSFs that appear unanimously less important than others.

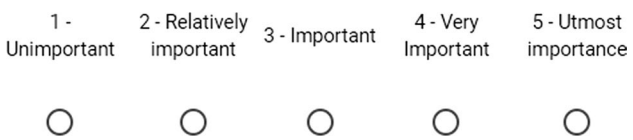

Fig. 1 Likert scale employed to evaluate CSF importance

3.3.1.2 Spearman's rank correlation coefficient In RIJVs, various CSFs are unlikely to operate in isolation. Instead, they interact in ways that can either enhance or diminish their individual effects on the project's success. For example, effective communication might be strongly correlated with clear statement of JV agreement, suggesting that improving communication could also positively impact the understanding of the JV agreement [26]. Identifying such correlations helps in prioritising and managing these factors more effectively.

Furthermore, Spearman's rank correlation is particularly suitable for this questionnaire data, as it does not assume a linear relationship and can handle ordinal data [65], like Likert scale rankings. It provides insights into the strength and direction of the relationships between CSFs, enabling the understanding of CSFs that appear to be positively or negatively correlated. The understanding of these correlations can guide future research and strategic planning. If certain CSFs are found to be closely linked, it can lead to a more integrated approach in training, policy development, and operational strategies, ultimately enhancing the efficiency and effectiveness of RIJVs. The 4-step process proposed by Laerd Statistics [66] was used to determine the correlation coefficients.

The output from SPSS provided the Spearman's rho values for each pair of CSFs, indicating the degree of correlation. Values close to + 1 or -1 indicated a strong positive or negative correlation whilst values near 0 indicated a weak correlation. The significance levels of 0.01 and 0.05 were used to determine if the correlations were statistically significant, with 0.05 meaning a 5% probability of the outcome being down to chance and 0.01 meaning a 1% probability of the outcome being down to chance.

3.3.2 Qualitative analysis

3.3.2.1 Thematic analysis In the qualitative, unstructured section of the questionnaire, respondents were asked to list challenges and solutions to challenges involved in achieving the CSFs outlined in the previous quantitative section. Results of this were analysed through thematic analysis.

Inductive thematic analysis was the selected approach as this involves deriving and identifying themes from the data with no preconceptions [67], an aspect of this qualitative research for all three questions. The six steps of thematic analysis by Naeem [67] were utilised, involving selection of quotations, keywords, coding, themes, conceptualisation and development of conceptual model.

1) Selection of quotations through data familiarisation: The raw data was exported from Google Forms and cleaned to present individual responses to each question. Duplicated answers were deleted, but their frequency noted, and shortened to develop manageable sentence sizes.
2) Keywords: From the cleaned data, keywords and phrases were identified as patterns which served as the initial base to form codes.
3) Coding: Complex textual data was simplified into short phrases and words to form fundamentals for potential themes.
4) Themes: Codes were organised into meaningful groups, allowing the identification of patterns and relationships. Each question provided the formation of four themes.
5) Conceptualisation: Developed themes were further refined and adjusted to accurately reflect the relationships and grouping of codes
6) Development of conceptual model: Lucid Charts [68], a mind mapping software, was utilised to develop thematic maps for each question, displaying their four main themes as well as codes used to generate these themes. The results of the conceptual model are shown in the results section and evaluated in the discussion section.

4 Findings

4.1 Demographics of the respondents

Forty responses from construction professionals experienced in RIJVs were collected via questionnaires. Respondents mainly had commercial backgrounds (52.5%), followed by engineering (17.5%) and project management (12.5%) as shown in Fig. 2. The dominance of commercial backgrounds is due to the numerous roles in this category, like

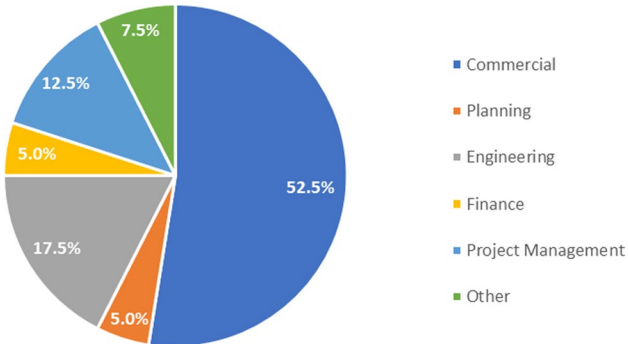

Fig. 2 Respondent working background

quantity surveyors, bid managers and estimators [69], and the research's significant commercial aspects related to CSFs, enhancing the relevance of results.

Respondents provided their years of experience in the construction industry (Fig. 3) and in RIJVs (Fig. 4). Figure 3 shows 37.5% have 5–10 years of industry experience, with 42.5% having over 10 years. Figure 4 indicates 45% have 3–5 years of RIJV experience, and 35% have over 5 years. This data highlights their extensive experience, ensuring accurate and reliable evaluations. These experienced professionals offer valuable insights into challenges and solutions in RIJVs, aiding strategic planning, risk management, and best practices.

4.2 Quantitative

4.2.1 Ranking of CSFs

Weighted mean and Relative Importance Index (RII) were calculated from importance rankings of the 20 CSFs identified from existing. Weighted mean and RII were calculated in MS Excel. This approach normalised the scores, allowing for a comparison of the relative importance of each CSF. The resulting RII values, ranging between 0 and 1, provided a clear hierarchy of CSFs based on their perceived importance by the professionals as shown in Fig. 5.

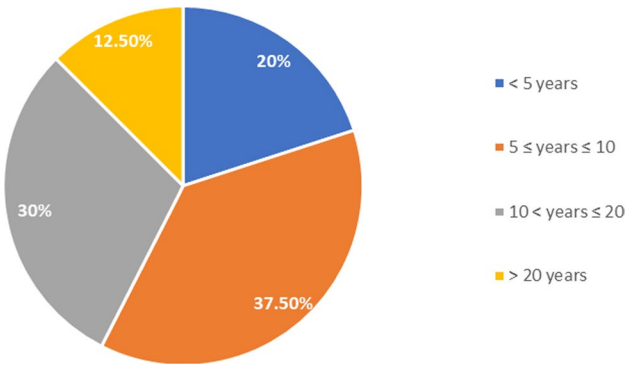

Fig. 3 Respondent construction industry experience

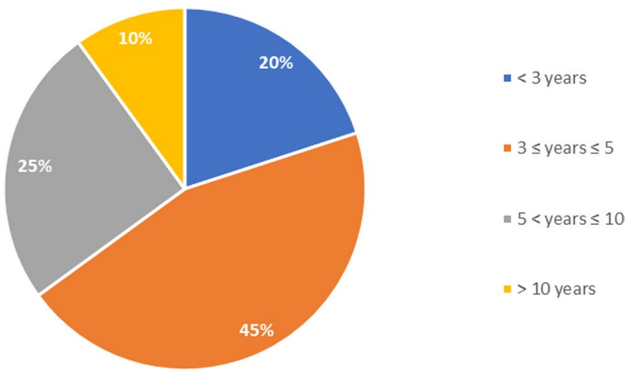

Fig. 4 Respondent RIJV experience

Critical Success Factor	Number of responses indicating 'utmost importance [5]'	Number of responses indicating 'unimportant [1]'	Weighted mean importance	RII	Rank * (based on RII)
Communication	32	0	4.80	0.96	1
Compatibility of partner objectives	25	0	4.63	0.925	2
Suitable JV partner selection	26	0	4.58	0.915	3
Trust	26	0	4.55	0.91	4
Effective planning	18	0	4.30	0.86	5
Financial stability of partners	13	0	4.25	0.85	6
Clear statement of JV agreement	15	0	4.23	0.845	7
Obtaining enough potential partners information	14	0	4.23	0.845	8
Level of participation and involvement	12	0	4.18	0.835	9
Management control	13	0	4.15	0.83	10
Expertise and confidence between partners	10	0	4.15	0.83	11
Intent to learn	7	0	4.00	0.8	12
Partner experience	13	0	3.93	0.785	13
Conflict frequency and resolution among partners	8	0	3.85	0.77	14
Complimentary technical skills and resources	6	0	3.75	0.75	15
Effective human resource management	6	0	3.63	0.725	16
Control of the majority ownership of capital	2	0	3.33	0.665	17
Cultural differences between partners	0	0	3.28	0.655	18
Profit focus of the JV	0	1	3.05	0.61	19
Size of firms	0	7	2.33	0.465	20

Fig. 5 Ranking of CSF importance according to RII values. *CSFs with equal RII values ranked according to the number of indicating 'utmost importance' [5]

'Communication' was ranked as the most important CSF for RIJVs, with an RII of 0.96 and 32 out of 40 respondents rating it as 'utmost importance'. Communication is fundamental for understanding partners' goals, capabilities, and roles [17]. Following closely were 'compatibility of partner objectives', 'suitable JV partner selection', and 'trust', each within 0.08 weighted mean importance and 0.015 RII, suggesting these CSFs are nearly equally important and potentially interconnected, a concept that has also been explored under data analysis in the subsequent section.

The literature review revealed 5 CSFs considered important for construction projects given their reoccurrence in a plethora of existing literature. Table 2 compares the CSFs considered most important according to existing literature and those revealed as ranked most important by respondents according to RII and weighted mean importance.

Table 2 CSFs considered important in existing literature for construction JVs compared to those considered important by respondents on RIJVs

5 Most important CSFs from research	5 Most important CSFs in existing literature (based on frequency)
Communication*	Management control
Compatibility of partner objectives	Compatibility of partner objectives
Suitable JV partner selection	Suitable JV partner selection
Trust	Trust
Effective planning*	Clear statement of JV agreement

*CSFs that differ from existing literature

The rankings for 'compatibility of partner objectives', 'suitable JV partner selection', and 'trust' align with existing literature. However, 'effective planning' and 'communication' were ranked within the top 5 CSFs by the respondents, suggesting the perceived importance of these CSF in RIJVs. Weighted means, ranging from 4.80 to 2.33, highlight a clear prioritisation of certain CSFs. There is strong consensus on the importance of top-ranked CSFs, evidenced by high Likert scale responses, while lower-ranked CSFs show diminished consensus about their level of importance.

4.2.2 Correlation between CSFs on RIJVs

Figure 5 reveals similarly ranked CSFs, suggesting potential interconnections. Consequently, Spearman's rank correlation analysis was employed to identify significant relationships among CSFs, providing insights into their interactions within the context RIJVs. This method, previously used by Hwang et al. [70] for construction JVs, underscores its relevance to JV research.

Figure 6 presents the Spearman's correlation coefficients for CSFs in RIJVs. Significant correlations are evident among various CSF pairs. Out of 210 possible correlations, 43 displayed strong positive correlations at the 0.05 and 0.01 levels, indicating robust interrelationships. Notably, 20 of these correlations were very strong at the 0.01 level, implying only a 1% chance that these correlations occurred randomly. This strongly supports rejecting the null hypothesis of no correlation between CSFs [71].

The strongest correlation was between CSF 10 ('intent to learn') and CSF 11 ('level of participation and involvement') ($r_s = 0.675$), indicating that increased willingness to learn is linked to higher participation. Similarly, CSF 8 ('communication') and CSF 9 ('trust') had a strong correlation ($r_s = 0.645$), and CSF 3 ('compatibility of partner objectives') and CSF 7 ('management control') showed a strong correlation ($r_s = 0.536$), all significant at the 0.01 level. These findings will be discussed further.

4.3 Qualitative

4.3.1 Challenges

Industry professionals identified four primary themes: information management and IT systems integration, alignment, congruency and synergy, inter-organisational dynamics, and strategic management (see Fig. 7).

Information management and IT systems integration highlighted challenges such as disparities in IT systems and document transfer issues between JV partners, underscoring the technical difficulties in ensuring smooth information flow.

Alignment, congruency, and synergy focused on achieving objectives alignment, congruent procedures, and a collaborative approach throughout the project lifecycle, emphasising the need for a unified direction and understanding among JV partners.

Inter-organisational dynamics brought forth challenges related to cultural differences, power dynamics, and trust issues within JVs, illustrating the complexities of collaboration among diverse entities and the impact of human factors on JV performance.

Strategic management pointed to difficulties in human resource management, external pressures, and the need for a clear hierarchy, indicating that strategic oversight and clear management structures are crucial for overcoming barriers to JV success.

	Critical Success Factor (CSF)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Suitable JV partner selection	Correlation	1.000																			
		Sig. (2-tailed)	0																			
2	Control of the majority ownership of capital	Correlation	0.301	1.000																		
		Sig. (2-tailed)	0.059	0																		
3	Compatibility of partner objectives	Correlation	.402*	0.310	1.000																	
		Sig. (2-tailed)	0.010	0.052	0.000																	
4	Clear statement of JV agreement	Correlation	0.190	0.211	0.120	1.000																
		Sig. (2-tailed)	0.240	0.190	0.462	0.000																
5	Obtaining enough potential partners	Correlation	.346*	0.056	0.204	.419**	1.000															
		Sig. (2-tailed)	0.029	0.733	0.207	0.007	0.000															
6	Cultural differences between partners	Correlation	-0.087	0.260	-0.119	0.183	0.046	1.000														
		Sig. (2-tailed)	0.595	0.105	0.465	0.259	0.779	0.000														
7	Management control	Correlation	.421**	0.299	.536**	0.015	0.184	0.082	1.000													
		Sig. (2-tailed)	0.007	0.061	0.000	0.929	0.256	0.617	0.000													
8	Communication	Correlation	.326*	-0.049	0.258	.361*	0.268	-0.150	.462**	1.000												
		Sig. (2-tailed)	0.040	0.762	0.108	0.022	0.095	0.357	0.003	0.000												
9	Trust	Correlation	0.185	-0.132	.362*	0.188	0.217	-.378*	.396*	.645**	1.000											
		Sig. (2-tailed)	0.253	0.416	0.022	0.246	0.179	0.016	0.011	0.000	0.000											
10	Intent to learn	Correlation	-0.012	0.080	0.272	0.052	0.003	0.016	0.033	0.144	.325*	1.000										
		Sig. (2-tailed)	0.941	0.625	0.090	0.749	0.984	0.923	0.841	0.375	0.041	0.000										
11	Level of participation and involvement	Correlation	0.041	0.055	0.239	0.076	0.093	0.242	-0.032	-0.040	0.111	.675**	1.000									
		Sig. (2-tailed)	0.799	0.735	0.137	0.639	0.570	0.132	0.845	0.804	0.497	0.000	0.000									
12	Expertise and confidence between partners	Correlation	0.181	0.201	0.163	.520**	0.216	-0.131	0.034	0.290	.419**	0.298	.319*	1.000								
		Sig. (2-tailed)	0.264	0.214	0.315	0.001	0.180	0.422	0.835	0.070	0.007	0.062	0.045	0.000								
13	Conflict frequency and resolution among	Correlation	0.203	0.021	0.072	.419**	0.267	0.098	0.037	0.205	0.188	0.042	0.131	.333*	1.000							
		Sig. (2-tailed)	0.209	0.897	0.657	0.007	0.096	0.547	0.820	0.205	0.246	0.798	0.420	0.036	0.000							
14	Effective planning	Correlation	.448**	0.196	0.044	.396*	0.178	0.297	0.205	0.226	0.221	0.207	0.236	.428**	.343*	1.000						
		Sig. (2-tailed)	0.004	0.226	0.787	0.011	0.273	0.062	0.204	0.162	0.171	0.201	0.142	0.006	0.030	0.000						
15	Complimentary technical skills and resources	Correlation	0.237	0.291	-0.022	.332*	0.118	0.272	0.040	0.056	-0.053	.464**	.504**	.350*	0.236	.398*	1.000					
		Sig. (2-tailed)	0.141	0.069	0.893	0.036	0.470	0.089	0.805	0.730	0.746	0.003	0.001	0.027	0.143	0.011	0.000					
16	Size of firms	Correlation	-0.033	.359*	-0.228	0.112	0.080	.427**	-0.134	-.348*	-.550**	0.119	0.236	0.040	0.121	0.209	.403**	1.000				
		Sig. (2-tailed)	0.840	0.023	0.157	0.491	0.624	0.006	0.410	0.028	0.000	0.466	0.142	0.804	0.456	0.195	0.010	0.000				
17	Partner experience	Correlation	0.223	0.200	0.095	0.045	0.142	-0.192	0.131	-0.040	0.050	0.050	0.087	0.263	-0.012	0.097	0.228	0.252	1.000			
		Sig. (2-tailed)	0.167	0.216	0.562	0.784	0.382	0.234	0.419	0.806	0.760	0.757	0.593	0.101	0.943	0.553	0.156	0.117	0.000			
18	Financial stability of partners	Correlation	0.128	0.170	-0.116	.353*	0.177	0.038	-0.030	0.103	-0.054	0.273	0.226	.465**	0.160	.328*	.427**	.402*	.456**	1.000		
		Sig. (2-tailed)	0.432	0.295	0.475	0.025	0.274	0.817	0.852	0.526	0.740	0.088	0.161	0.003	0.323	0.039	0.006	0.010	0.003	0.000		
19	Effective human resource management	Correlation	-0.064	0.205	0.100	.404**	0.156	0.035	-0.122	0.043	0.049	.385*	.378*	0.308	-0.035	0.155	.378*	0.150	0.183	.373*	1.000	
		Sig. (2-tailed)	0.694	0.204	0.539	0.010	0.335	0.831	0.453	0.791	0.765	0.014	0.016	0.054	0.832	0.339	0.016	0.357	0.259	0.018	0.000	
20	Profit focus of the JV	Correlation	-0.186	0.196	-.332*	0.139	-0.048	0.271	-0.245	-0.173	-0.206	0.183	0.118	0.021	0.097	0.024	0.078	.456**	-0.032	.348*	0.270	1.000
		Sig. (2-tailed)	0.252	0.226	0.036	0.391	0.768	0.091	0.128	0.285	0.202	0.258	0.469	0.898	0.550	0.885	0.634	0.003	0.844	0.028	0.092	0.000

Fig. 6 Spearman's correlation between CSFs in RIJV

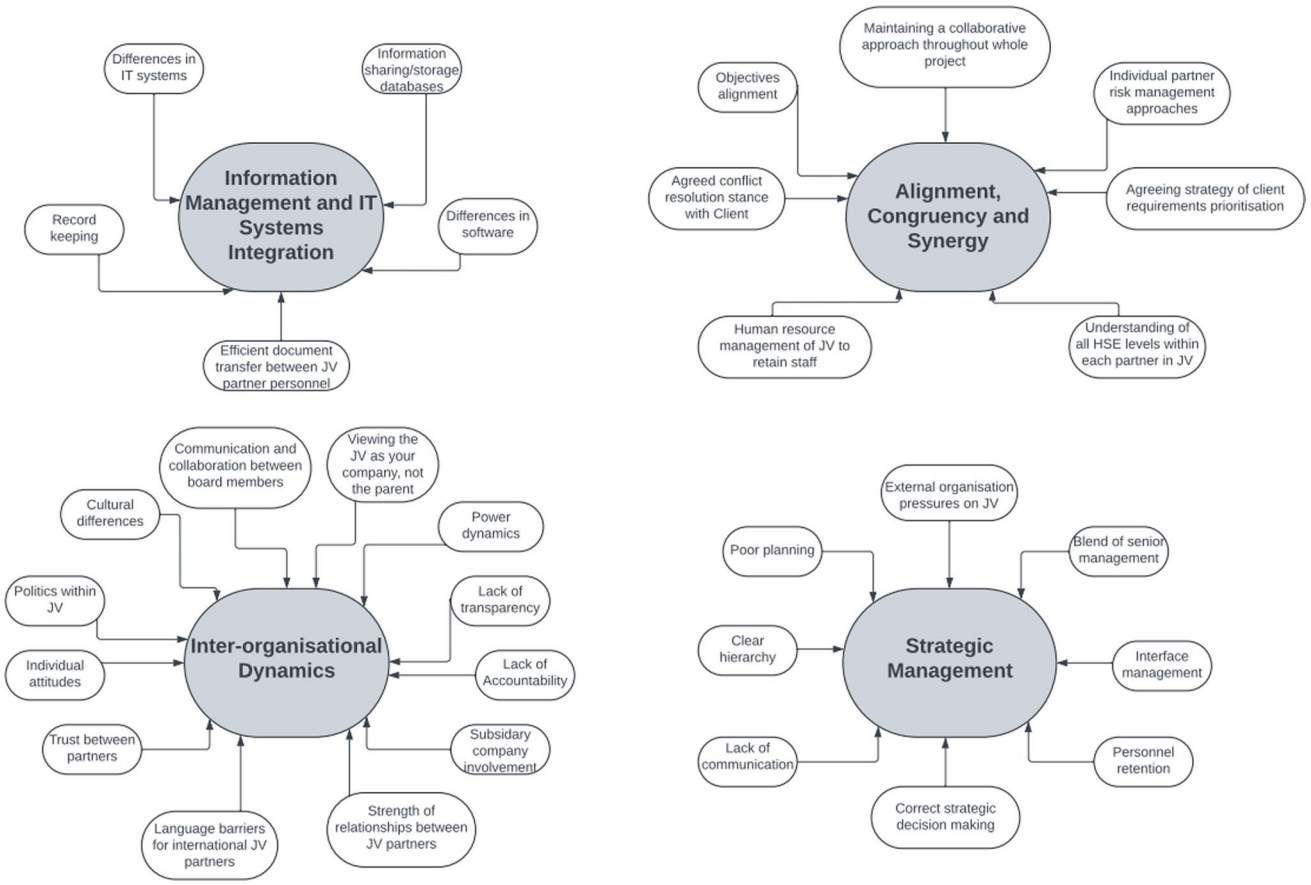

Fig. 7 Thematic map detailing common themes amongst RIJV challenges

This analysis provides a comprehensive picture of RIJV challenges, revealing that success depends not only on technical and strategic factors but also on the quality of inter-partner relationships and the ability to navigate complex organisational dynamics.

4.3.2 Solutions

Thematic analysis of responses identified four themes: strategic management and leadership, collaboration and communication, risk management and conflict resolution, and operational/information efficiency and resource optimisation.

In strategic management and leadership, respondents emphasised selecting complementary partners, establishing clear organisational structures, and developing coherent leadership strategies as key to forming a strategic framework conducive to project success.

For collaboration and communication, respondents advocated for regular internal performance meetings and stakeholder engagement. Building trust through open communication, workshops, and removing political wrangling were seen as essential for fostering a collaborative environment.

Regarding risk management and conflict resolution, adopting a uniform risk management style and prioritising early conflict resolution were identified as effective mechanisms to mitigate risks. In operational/information efficiency and resource optimisation, ensuring operational excellence involved robust training schemes and adopting standardised software and tools, including AI.

The thematic map in Fig. 8 shows that overcoming challenges in RIJVs requires a comprehensive and integrated approach. This includes strong strategic direction, enhanced collaboration, proactive risk management, and operational efficiency—all interlinked and essential for navigating the challenges inherent in RIJVs.

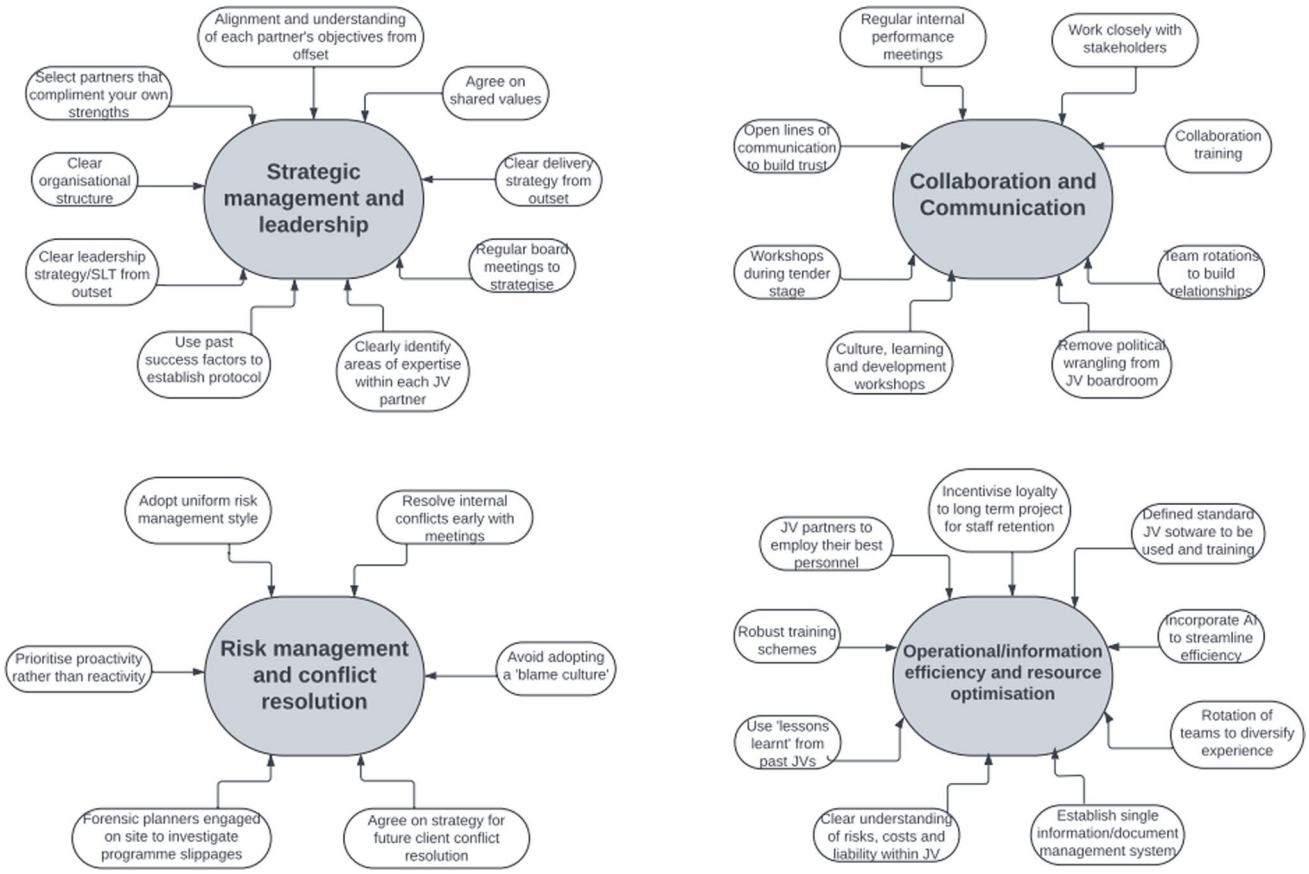

Fig. 8 Thematic map detailing common themes in solutions to RIJV challenges

5 Discussion

5.1 Most important CSFs for RIJVs

The RII rankings in Fig. 5 identify 'communication' as the highest-ranked CSF for RIJVs. This is due to the complexity of rail infrastructure projects, which require extensive planning, efficient resource allocation, and coordination of diverse tasks. Effective communication aligns all parties with project objectives and schedules, mitigating misunderstandings and misalignments that can cause delays and cost overruns [72]. Additionally, RIJVs often involve partners from different backgrounds and cultures. Efficient communication is essential for bridging cultural and language differences, ensuring consistent understanding of project goals, and facilitating collaboration and decision-making in complex projects [64, 73].

Furthermore, RIJVs involve multiple stakeholders, including government entities, regulatory bodies, and the public. High profile projects, for example HS2, face significant stakeholder pressure due to their public interest and impact on communities, the environment, and local economies [74]. Effective communication ensures consistent messaging to these stakeholders, maintaining trust and support, which are crucial for project execution and acceptance.

'Compatibility of partner objectives' and 'suitable JV partner selection' rank second and third, respectively, with only a 0.01 RII difference. RIJVs are long-term projects with substantial financial and technical commitments. 'Compatibility of partner objectives' ensures a shared vision and agreement on project goals, timelines, risk-sharing, and financial arrangements [37]. This alignment minimises conflicts and diverging strategies.

The diverse nature of rail infrastructure tasks requires a wide range of expertise. 'Suitable JV partner selection' involves choosing partners based on technical and financial capabilities and their ability to complement each other's strengths. A balanced mix of partners brings together varied skills and resources crucial for RIJVs.

The regulatory, environmental, and social implications of rail projects demand comprehensive management strategies. Partners with compatible objectives and complementary strengths are better equipped to navigate these

aspects, ensuring regulatory compliance, environmental sustainability, and community acceptance. Thus, aligning partner objectives and selecting suitable partners is fundamental for successful collaboration in RIJVs, capable of overcoming intricate challenges.

5.2 Inter-connection of CSFs in RIJVs

5.2.1 CSF 10, 'intent to learn', and CSF 11, 'level of participation and involvement'

CSFs 10 and 11 are deeply interlinked, with Spearman's rank test showing the highest correlation ($r_s = 0.675$). This relationship underscores the mutual reinforcement of collaborative learning and active engagement in complex projects.

'Intent to learn' represents JV partners' commitment to acquiring new knowledge, crucial in an industry marked by regulatory updates and evolving best practices [37]. This fosters a culture of continuous improvement, innovation, and adaptation, essential for tackling unique rail infrastructure challenges [75].

'Participation and involvement' refers to partners' active engagement in the JV's processes and decision-making. Deep involvement allows partners to contribute expertise and gain practical insights, creating a dynamic learning environment. The positive correlation between these CSFs suggests that a strong intent to learn enhances participation, as engaged partners seek learning opportunities, creating a beneficial feedback loop. Increased involvement further encourages a willingness to learn, positively influencing the JV's success.

Active involvement provides practical scenarios for applying new knowledge, reinforcing 'intent to learn', which is critical for acquiring knowledge [76]. The synergy of these CSFs enhances the JV's expertise and capacity, driving innovation and efficiency in managing rail infrastructure projects.

Fostering an environment where learning and involvement are intertwined is vital for RIJV success, ensuring that the partnership leverages collective learning for improved performance and outcomes.

5.2.2 CSF 8, 'communication', and CSF 9, 'trust'

CSFs 8 and 9 are closely linked, with a strong positive correlation ($r_s = 0.645$). Effective communication is essential for building and maintaining trust among JV partners, particularly in projects with technical complexity, regulatory compliance, and stakeholder management.

Lu et al. [40] emphasises that clear communication is crucial in large-scale projects, ensuring clarity and coordination among diverse teams. This communication builds trust, essential for managing complex planning, execution, and stakeholder engagement. Trust, in turn, enhances open and effective communication, creating a positive feedback loop [77].

This synergy is critical for overcoming the challenges of RIJVs, where mutual reliance and clear information exchange are key to successful collaboration. The interdependence of communication and trust forms a cycle vital for the smooth execution of complex projects, directly influencing their ability to achieve success.

5.2.3 CSF 3, 'compatibility of partner objectives', and CSF 7, 'management control'

CSFs 3 and 7 are linked, with a positive correlation ($r_s = 0.536$). In RIJVs, aligning partner objectives is fundamental for setting a unified strategic direction, streamlining decision-making, and enhancing management control. This alignment is essential for managing large-scale coordination, substantial investments, and regulatory compliance [31].

Effective management control ensures that aligned objectives are consistently pursued, overseeing project progress, managing risks, and ensuring compliance [42]. This synergy facilitates smooth execution of RIJVs by harmonising objectives and management practices.

Additionally, aligned objectives enhance risk management, allowing partners to develop and implement comprehensive strategies collaboratively. This unity ensures effective identification, assessment, and mitigation of technical, financial, and regulatory risks. Agreed-upon contingency plans and resource allocations lead to smoother crisis management, bolstering project resilience and solidifying trust and cooperation among partners.

The link between 'compatibility of partner objectives' and 'management control' is thus critical for successful RIJVs, fostering a unified approach to risk handling and project governance.

5.3 Challenges

The thematic analysis of responses identified four main themes for addressing CSF challenges in RIJVs: information management and IT systems integration, inter-organisational dynamics, alignment, congruency and synergy, and strategic management.

Efficient information management is crucial in rail infrastructure projects due to their complexity and extensive documentation. Challenges stem from differing IT systems and software among JV partners, affecting record-keeping, data sharing, and storage. Integration of systems, as highlighted by Patacas et al. [78], facilitates efficient document transfer and project continuity, encapsulated in the concept of a Common Data Environment (CDE).

Inter-organisational dynamics capture the complexity of relationships between JV partners. Cultural differences, individual attitudes, and internal politics can hinder communication and collaboration. Trust is essential, especially in international JVs where language barriers add complexity. Power dynamics, transparency, and accountability significantly influence JV operations' efficacy.

Aligning diverse objectives and risk management approaches of JV partners is a significant challenge. A collaborative approach is needed throughout the project, including harmonising strategies for prioritising client requirements and resolving conflicts. Mba and Agumba [79] categorise these challenges under "*ambiguity of responsibilities*", emphasising the need for clear articulation of approaches and reducing lack of clarity. Specific examples include alignment in human resources, HSE levels, and client conflict resolution strategies.

Strategic management involves the overall guidance of the JV. Challenges include establishing a clear hierarchy, managing external pressures, ensuring effective interface management, and personnel retention. Poor planning and communication can disrupt strategic decision-making, underscoring the need for cohesive leadership to navigate the JV through its strategic objectives.

5.4 Solutions

The analysis of construction professionals' responses revealed key solutions within four themes to address the challenges of CSFs for successful RIJVs: strategic management and leadership, collaboration and communication, risk management and conflict resolution, and operational/information efficiency and resource optimisation. These themes differ from those in the 'challenges' section, reflecting the dynamic and varied nature of solutions provided by construction professionals, which group together to form slightly differing themes yet still possess indirect and direct links.

In strategic management and leadership, the focus is on forming clear and complementary partnerships, selecting partners for their unique strengths, and fostering shared values and objectives. Regular strategic meetings and a clear organisational structure ensure unified direction and effective leadership.

Risk management and conflict resolution require a uniform approach to risk management, allowing for proactive strategies that address conflicts before they emerge [80]. Systematic conflict resolution mechanisms, such as regular meetings and a solution-focused culture, are essential for long-term success. Employing forensic planners for resolving program slippages can provide in-depth program analysis and better resolution strategies.

Open communication channels build trust and facilitate continuous dialogue, fundamental for collaboration. Structured training programs, team rotation, and workshops foster continuous learning and adaptability [81]. Removing political wrangling and focusing on collective goals within the JV boardroom enhances cooperation and project focus.

Operational/information efficiency and resource optimisation involve standardising JV software and employing technology like AI to optimise efficiency. AI tools such as artificial neural networks (ANN) and simulation techniques can increase efficiency [82]. Adequate training ensures personnel are proficient in these systems. Utilising lessons learned from past RIJVs can guide resource allocation, as similar issues are often encountered across different projects.

Each theme represents a multi-faceted approach to overcoming the intrinsic challenges in RIJVs. These solutions, ranging from strategic alignment to technological optimisation, contribute to creating a collaborative and efficient JV framework capable of achieving the set CSFs.

6 Conclusion and recommendations

This research aimed to evaluate the critical success factors of RIJVs, by investigating RIJVs where several contractors have come together to deliver a large-scale rail infrastructure project in the UK. The niche contribution of this research is the contextualisation of knowledge on CSFs for JV implementation, specifically within the context of JVs between contractors to deliver rail infrastructure projects. CSFs specifically within the context of RIJVs between contractors has been subjected to little academic research prior to the current research. Primary research revealed that communication, compatibility of partner objectives and suitable JV partner selection were seen as the most important CSFs for RIJV implementation. However, it is to be noted that these are 'perceived' important CSFs of RIJVs—future research should focus on detailed tracking of real-life projects to determine undisputed CSFs.

In relation to challenges of meeting the CSFs in RIJVs, Information Management and IT Systems Integration, Alignment, Congruency and Synergy, Inter-organisational Dynamics, and Strategic Management were identified as significant. Strategic Management and Leadership, Collaboration and Communication, Risk Management and Conflict Resolution, and Operational/Information Efficiency and Resource Optimisation were the four key themes identified as the strategies to overcome the challenges.

This research has conducted a comprehensive evaluation of the critical success factors for RIJVs, carving out a nuanced understanding of the key pillars of success in this complex field. By identifying and prioritising the most significant CSFs, it has highlighted the pathways to effective JV execution. The challenges inherent in actualising these CSFs were dissected and accompanied by innovative solutions, providing a blueprint for navigating the obstacles that stand in the way of RIJV success.

The expanding scope of the UK's rail network, a direct response to growing societal need for sustainable and efficient public transportation systems, further emphasises the importance of this study. Rail infrastructure developments do not only serve as a backbone for urban and inter-city movement but also play a vital role in advancing economic growth, connectivity, and social development. Significant investment is made on rail infrastructure as governments seek to meet these demands. As a result, major refurbishment and new developments for rail infrastructure are expected to arise for the next few decades, allowing the opportunity for large scale projects to be procured to increase for contractors, with the JV being a strategic collaboration many will look to explore given the aforementioned benefits. By understanding and harnessing the critical factors to a successful JV in this context, the complexities of a RIJV can be capably navigated by fostering collaboration, avoiding disputes where possible and delivering rail infrastructure projects of the highest standard. This will allow contractors in RIJVs to facilitate risk sharing, mitigate individual loss and capitalise on the complementary strengths of their adjacent partners to facilitate project delivery, maximise profit and allow potential for future JVs with the same partner together.

The sample size for the questionnaire was relatively small, with 40 respondents. A larger sample with a stratified random sample could increase reliability and reduce the chance of statistical anomalies. The questionnaire was contractor-focused—including client-side responses could provide diverse perspectives on RIJV success. The questionnaire targeted professionals from two major RIJVs on the same project. Involving more RIJVs from a range of projects could offer a broader range of expertise and improve data accuracy and reliability. Further research can be undertaken to analyse RIJVs in different countries or regions to understand how regional regulatory frameworks, cultural differences, and economic conditions influence CSFs, providing a more contextualised understanding of success. Research can also explore how emerging technologies like BIM and AI impact CSFs in RIJVs, emphasising innovation as a success factor. Further, adopting a stakeholder-centric approach, particularly in high-profile RIJVs, further research needs to evaluate how stakeholder engagement, satisfaction, and communication strategies contribute to overall success, incorporating perspectives from government bodies, local communities, and environmental groups.

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Author contributions AB undertook the research under the supervision of GW and MOT. AB wrote the first draft of the manuscript. GW and MOT edited and revised the manuscript. AB and GW revised the manuscript based on reviewer feedback. All authors reviewed the manuscript.

Data availability Data sets generated during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate Ethical approval for the study was obtained as per the ethics standards of Aston University. University. All procedures performed in the study were in accordance with the ethical standards of Aston University. Informed consent was obtained from all individual participants included in the study

Competing interests The authors declare no competing interests.

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