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Critical Success Factors of University-Industry R&D Collaborations

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Abstract

University-industry R&D collaborations (UICs) play a vital role in stimulating open innovation that leads to new products, processes, and services that creates value for customers and broader societal impact. UICs, however, commonly fail to meet these stakeholders' benefits. This study identifies thirty-four critical success factors (CSFs) for improving UIC success. The study includes a systematic literature review and a longitudinal UIC case study between Bosch Car Multimedia in Portugal and University of Minho, a multi-million Euro R&D collaboration from 2013 to 2021. The importance of the CSFs is discussed in the context of the UIC lifecycle. A survey among researchers and industry practitioners involved in R&D collaborative projects was completed to confirm the analysis of the empirical results. This paper provides UIC managers with CSFs, which, when addressed competently, can provide a basis for successful UIC projects and sustainable university-industry collaborations.

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1. Introduction

Companies are more open to investment in research and development (R&D), and this positively influences university-industry R&D collaborations (UICs) [1]. Companies increasingly recognise that collaborating with universities enhances their innovation capabilities [2]. Collaboration transfers existing knowledge among organisations, facilitates new understanding and produces synergistic solutions [3]. R&D collaboration is viewed as an essential input to innovation [4] and is encouraged by governments to enhance national competitiveness and wealth creation [5].

While there is an increasing prevalence of UICs, many often fail to meet stakeholders' expected benefits [7, 8]. This failure is often a consequence of a lack of partner trust; unclear objectives; objectives not aligned with partners' strategy; poor planning; and reduced flexibility and agility within the management structure [6]. Literature concerning UICs has focused on the macro-level of UIC implementation that include the critical channels of interaction between universities and industry, the implementation mechanisms of building trust, the barriers and challenges faced by partners, and the dynamics of triple helix infrastructures [8, 9]. An inherent criticism made of these studies is that they are too focused on the outputs of UICs rather than on the management process that can identify what is critical for UIC success [10].

Managing UICs presents many issues. One of the most important is the cultural gap between universities and industries [11]. However, most problems associated with the cultural gap can be alleviated by good project management (PM) [12]. PM has long been viewed as a critical innovation management mechanism for implementing projects [13]. Although essential, in the context of UICs, this view is simplistic. Interactions between the university and industry are increasingly being managed more actively, leading to more formal contractual arrangements based on codified norms and standards [14]. However, there is a need to consider both the technical and social aspects of management. For example, the lack of rigorous governance is often regarded as one of the most critical barriers to project success [15].

Research into project Critical Success Factors (CSFs) is still a growing field of research [16]. The success factor concept is usually credited to Daniel [17], who was concerned with the 'management information crisis' [18]. This approach has many supporters. In project management research, several studies have used this approach [18-21]. In addition, Pinto and Slevin [22] have demonstrated that CSFs vary across industries and project types. Some CSFs have been identified that facilitate collaborative R&D.

The key objective of this research is to identify the CSFs for managing UICs. This research attempts to answer the research question: "What are the critical success factors of university-industry R&D collaborations?" In addition, an initial attempt is made to recognise the level of importance of each CSF throughout the UIC lifecycle, to overcome a common criticism of the CSF approach encapsulated in "the factor approach tends to view implementation as a static process instead of a dynamic phenomenon, and ignores the potential for a factor to have varying levels of importance at different stages of the implementation process" [23, p.398].

This paper begins with a literature review followed by an explanation of the research methodology or steps taken to collect and analyse primary data in a case study. The research reduced forty-two CSFs identified from the literature review to thirty-four CSFs perceived in the case study. The main findings emerging from the study are discussed, followed by conclusions, limitations, and future work.

2. Critical success factors of university-industry R&D collaborations

A systematic literature review helped to identify forty-two CSFs in UICs. These are summarised in Table 1. The research articles studied were identified by using the Scopus and Web of Science databases and using the search strings: ("critical factors" OR "critical success factors") AND ("universit*-industr*" or "industr*-universit*" or "academ*-industr*" or "industr*-academ*"). Fifty-seven journal papers and book chapters published in English between 2000 and 2021 were initially discovered, and following screening, this was reduced to twenty-two articles. Among these twenty-two articles, six relevant studies are now briefly highlighted and shed further light on the construction of Table 1.

One of the most relevant studies found was from Barnes, Pashby, and Gibbons [6]. They categorised critical factors into different themes: universal success factors; ensuring quality; choice of partner; project management; environmental factors and; cultural gap. Some of the CSFs highlighted included trust, flexibility, leadership, learning, motivation, research interactions with industry partners, complementary experience, interpersonal relationships, previous collaborative experience, competent project managers, adequate resources, regular monitoring and control, clear roles and responsibilities, corporate stability, qualified and skilled teams, reputation of stakeholders, balanced benefits realisation, effective communication, shared vision and straightforward and realistic goals.

Another study from Mora-Valentin et al. [15] based on a survey of an extensive database of UICs projects of a Spanish funding agency identified ten CSFs of UICs. Five are associated with contextual factors: previous links; partners' reputation; definition of objectives; institutionalisation of rules; policies and procedures for project management and governance and; geographic proximity. Five were related to organisational factors, such as commitment; communication; trust; conflict and; dependence.

Among subsequent studies, Pertuzé [24] identified practices that contribute to UIC success, including the: selection of collaboration projects that complement company R&D; selection of university researchers who understand specific industry goals and practices; choosing project managers with solid boundary spanning capabilities, investing in long-term relationships; providing appropriate internal support for the project; and building awareness of the university project inside the company, through effective communication.

Sandberg et al. [25] identified ten influential factors in the UIC case study between Ericson and IT University in Sweden. Five are associated with research activity such as: management engagement; network access; collaborator match (e.g., complementary expertise); effective communication and; continuity or long-term perspective. Five are related to research results, namely: orientation to industry issues (real-life); alignment with industry goals; deployment impact; benefits for the industry and; innovativeness. Regarding the research results, Sandberg et al. [25] focused on the industry expectations disregarding the university's expectations from such collaborations [2].

Later, Ankrah and Al-Tabbaa [3] identified several CSFs that facilitate or impede R&D collaborations. They categorised these factors into five main categories: capacity and resources; legal and contractual mechanisms; management and organisation; technology; political, social and other issues.

Finally, a recent study from Pinto and Pinto [16], through the current scholarship on success and CSFs [18], examined how these concepts form a critical knowledge base for translating the planning and organisation of collaborative R&D project activities into successful projects.

It is worth mentioning that the CSFs described in Table 1 might be named differently by authors. For example, the CSF ‘Senior Management Commitment’ may be termed as ‘upper management buy-in’ or ‘board sponsorship support’.

Table 1. Critical success factors from literature review.

ID	Critical Success factors	Description	References
CF.01	Senior Management Commitment	Perception within the project team and its stakeholders that the project is supported (publicly and financially) by the top management of each partner.	[6], [15], [25], [3], [16], [26]
CF.02	Clear and Realistic Goals	Initial clarity and general agreement on project objectives and expectations.	[6], [15], [16], [26], [27]
CF.03	Mutually Agreed and Updated Work Plan and Deliverables	Formulation of a detailed and continuously updated plan, agreed by the different project partners.	[16], [27], [28]
CF.04	Effective Communication	Existence of an adequate information system and availability of all necessary data to the main stakeholders throughout the project.	[6], [15], [24], [3], [16], [28]
CF.05	Stakeholder Engagement	Consultation and active listening to key stakeholders throughout the project lifecycle.	[6], [15], [25], [16], [28]
CF.06	Qualified and Skilled Teams	Technically qualified members, competent to perform their functions in the project, and with soft skills suitable for the expected performance.	[6], [16], [29]
CF.07	Reputation of Stakeholders	Recognized prestige and excellence in the business area of the project stakeholders.	[15], [3], [28], [30], [31]

ID	Critical Success factors	Description	References
CF.08	Effective Change Management	Ability to handle unexpected changes or deviations in the original project plan; flexibility promoting the creativity of stakeholders.	[16]
CF.09	Competent Project Managers	Technically and administratively capable project manager, with leadership skills and knowledge of the organisational culture.	[6], [24], [16]
CF.10	Shared Vision and Goals	Partners who share the same vision and goals for project implementation.	[6], [16]
CF.11	Clearly Allocated Resources	The project team contains a sufficient number of members clearly allocated to project activities.	[16], [26], [27]
CF.12	Good Leadership	Managers with leadership skills, inter-organisational vision, ability to motivate and develop teams.	[6], [16]
CF.13	Realistic Schedules	The project schedule is seen as reasonable and developed through a careful joint analysis of the partners, with the contribution of all major stakeholders.	[16]
CF.14	Risk Management	The identification, analysis, and responses to the risks of the project are carried out on a continuous basis, in order to support the key decisions of the project.	[16]
CF.15	Collaboration Champions	A senior member identified in each partner who serves as the visible sponsor of the project; a champion committed to supporting the project throughout its life cycle.	[6], [16]
CF.16	Regular Monitoring & Control	Continuous monitoring of project status with timely feedback to project stakeholders (e.g., progress reports throughout the project lifecycle).	[6], [24], [16], [26]
CF.17	Adequate Budgeting	The perception of the different parties involved is that the budget is sufficient for the development of the project.	[16], [27]
CF.18	Adaptive Cultures	Solidary organisational cultures and a flexible and agile inter-organisational structure that allows the project to develop and progress.	[16]
CF.19	Effective External Subcontractors	Subcontracted external entities are responsible and zealous in fulfilling their functions in the project.	[16]
CF.20	Appropriate Methodology for Project Management	Use of project management methodologies adapted to the context of each project, which provides a balance between control and creative freedom.	[6], [15], [24], [3], [16], [27], [32]
CF.21	Good Governance	Definition of an appropriate inter-organisational project governance structure (e.g., project organisation chart).	[15], [31], [33]
CF.22	Corporate Stability	Internal and inter-organisational corporate stability, i.e., between the top management of the different partners, ensuring internal or external financial support to the project (e.g., public funding).	[6], [3], [16], [34]
CF.23	Learning and Benchmarking	Use of lessons learned from past projects as reference mechanisms to improve project development.	[16]
CF.24	Appreciating Different Viewpoints	Different viewpoints of stakeholders are encouraged and taken into account.	[6], [16]
CF.25	Mutual Trust and Respect	Relationship of trust and mutual respect between partners throughout the project lifecycle.	[6], [15], [3], [28], [35],[36]
CF.26	Clear Roles and Responsibilities	Clear division of roles and responsibilities among the different parties involved in the project.	[6], [26], [27]
CF.27	Previous Collaborations and Experience	Partners have experience in R&D collaboration projects, or there has already been some form of collaboration between them.	[6], [15], [24]
CF.28	Teamwork	Good interaction, connection, and empathy between the members of the different partners.	[6], [3], [27], [28]
CF.29	Complementary Expertise	Selection of partners with the complementary knowledge necessary for technological developments; leading partners in the knowledge area.	[6], [24], [25], [27], [30]

ID	Critical Success factors	Description	References
CF.30	Equality of Power and Dependency	Real dependencies between project parties and perception of equality and balance among peers.	[6], [15]
CF.31	Mutual Benefits and Aligned with Partners' Strategy	Mutual benefits between the partners involved aligned with each partner's organisational strategy.	[6], [2], [25], [26]
CF.32	Mutual Understanding of Partners' Needs	Knowledge or experience of the partners' internal and external environment, allowing a greater understanding of their needs.	[6], [24], [28]
CF.33	Flexibility and Adaptability	Flexibility and adaptability, taking advantage of new paths or opportunities that arise during the course of the project.	[7], [6], [3]
CF.34	No Hidden Agendas	The absence of objectives not explicitly recognized and declared by the partners.	[6]
CF.35	Long-term Perspective	Vision of long-term collaboration and not just to achieve the outcomes of the ongoing project.	[25]
CF.36	Interactions Between Projects	Interactions between projects allowing the creation and use of synergies with high potential.	[6], [28], [37]
CF.37	Researchers Interactions with Industry Partner	Promotion of researcher interactions with industry partner to increase shared awareness of project impact.	[6], [27], [28]
CF.38	Political Support and Funding	Political support and relationship chains that facilitate obtaining external financing.	[3]
CF.39	Balanced Benefits Realisation	Equilibrated interests between the different project partners.	[6], [2], [25]
CF.40	Training Provision	Project team members receive sufficient technical or management training to perform their duties.	[6], [16]
CF.41	High Motivation	Project members are highly motivated for its realisation.	[6]
CF.42	Effective Conflict Management	Understanding that conflicts are part of the collaborative process, and their effective management is critical.	[25], [15], [26]

3. Method

The case study used in this research is a major UIC involving one sizeable multinational corporation – Bosch Car Multimedia Corporation (Bosch), one university – the University of Minho (UMinho) and a Portuguese government funding agency. Bosch and Minho agreed to propose the R&D program to the Portuguese funding agency in 2012. The UIC studied as part of this research comprised three phases of R&D activity between 2013 and 2015, 2015 and 2018, and 2018 and 2021, respectively. The first phase involved an investment of around €19m on a research program of 14 R&D projects and included circa 300 researchers. The second phase involved an investment of €54m on a research program of 30 R&D projects with almost 500 researchers. The third phase involved an investment of €91m on a research program of 57 R&D projects and above 500 researchers. The key application domains were electronics and instrumentation, information technology, mechanical technologies and materials, industrial engineering and management, and optical physics.

A small team of researchers followed the development of the UIC between the years 2014 and 2021. Part of this longitudinal study aimed to identify the perceived CSFs. Key university researchers and industry practitioners – nine from the university and five from the industry were requested to rank the CSFs identified in the literature in order of their impact on the effectiveness of the UIC on a scale from 1 (very low) to 5 (very high). All participants had been involved since the beginning of the collaboration and held responsibilities at the different levels of the governance structure. They included program managers, program and project management team, project managers, and project team members. Following information gathering from the fourteen individual participants, a focus group discussion was arranged to discuss how key CSFs might assume importance over the research collaboration lifecycle. The researchers employed the lifecycle adopted by the consortium, namely [38]: program preparation (commonly named a pre-award phase), program initiation (transitional phase), and program benefits delivery and program closure (post-award phase). CSFs were also classified according to their 'human', 'technical' or 'organisational' origin. The 'human' category concerns CSFs dependent on an individual's behaviours or attitudes and are more identifiable with 'soft' skills (e.g., trust, respect, motivation). The 'technical' CSFs are those that require technical skills or capabilities and are related to 'hard' skills, such as clear and realistic goals, risk management, training, etc. The 'organisational' category corresponds to CSFs that depend on the organisational culture, processes, and assets, such as its vision, goals, governance, and strategy.

4. Results and discussion

Table 2 presents the mean CSF scores in the face of their impact on the effectiveness of the UIC. There was wide agreement among the participants on the impact scores of these CSFs. The mean values attributed individually to each CSF vary between 3.1 and 4.7 on a scale of 1 (very low) to 5 (very high). The focus group provided a rich perspective and exchange of arguments in favour and against the relevance of each CSF. There was an explicit agreement on the top eight CSFs:

- Senior management commitment
- Effective communication
- Stakeholder engagement
- Good leadership
- Clear & realistic goals
- Mutual trust and respect
- Teamwork
- Clear roles and responsibilities

There was also reasonable agreement on CSFs that had the most negligible impacted the effectiveness of the UIC, namely:

- Appreciating different viewpoints
- No hidden agendas
- Reputation of stakeholders
- Equality of power and dependency
- Interactions between projects

The CSF 'Researchers interactions with industry partner' identified from the literature review was discussed and concluded to be common and implicit within the 'Teamwork' CSF. Also, the CSF 'Flexibility and adaptability' was implicit in the 'Adaptive cultures' CSF. These two CSFs could therefore be removed. Finally, the major projects (programs) were politically supported and funded, and therefore this was seen as a unique CSF. However, there are also unfunded UICs making it critical is to ensure the internal or external financial resources for the project. For this reason, a CSF is the 'Corporate stability' between the top management of the different partners. The analysis resulted in a final list of thirty-four CSFs.

There were some disagreements among university and industry participants regarding the impact of individual CSFs. The most significant difference observed was 'Corporate stability' (3.9/2.2 university/industry), followed by 'Collaboration champions' (4.0/2.6), 'Qualified and skilled teams' (4.6/3.4), and 'Competent project managers' (4.4/3.4). Interestingly, these CSFs were more valued by the university than industry participants. This was largely understandable due to cultural differences in the university and industry settings. It also reflected differences of opinion that result from viewing the CSF with different lenses, influenced by the specific characteristics and dynamics of the industry sector, namely those related to its workforce and markets [6]. Other research, such as Mora-Valentin [15], also found similar differences. In addition, CSFs concerning 'trust' [36] or 'senior management commitment' [6] were recognised as more critical to university than industry practitioners.

Table 2. Critical success factors mean scores.

Critical Success Factor	Mean	Critical Success Factor	Mean	Critical Success Factor	Mean
CF.01 Senior Management Commitment	4.7	CF.29 Complementary Expertise	4.0	CF.42 Effective Conflict Management	3.6
CF.04 Effective Communication	4.6	CF.03 Mutually agreed and Updated Work plan and Deliverables	4.0	CF.18 Adaptive Cultures	3.6
CF.05 Stakeholder Engagement	4.5	CF.23 Learning and Benchmarking	3.9	CF.15 Collaboration Champions	3.5
CF.12 Good Leadership	4.5	CF.31 Mutual Benefits and Aligned with Partners' Strategy	3.9	*CF.36 Interactions Between Projects	3.5
CF.02 Clear and Realistic Goals	4.4	CF.21 Good Governance	3.9	*CF.30 Equality of Power and Dependency	3.4
CF.25 Mutual Trust and Respect	4.4	CF.10 Shared Vision and Goals	3.9	*CF.07 Reputation of Stakeholders	3.4
CF.28 Teamwork	4.2	CF.13 Realistic Schedules	3.8	CF.40 Training Provision	3.4
CF.26 Clear Roles and Responsibilities	4.1	CF.16 Regular Monitoring & Control	3.8	*CF.34 No Hidden Agendas	3.4
CF.06 Qualified and Skilled Teams	4.1	CF.14 Risk Management	3.7	*CF.33 Flexibility and Adaptability	3.4
CF.11 Clearly Allocated Resources	4.1	CF.19 Effective External Subcontractors	3.7	CF.08 Effective Change Management	3.3
CF.09 Competent Project Managers	4.1	CF.32 Mutual Understanding of Partners' Needs	3.7	CF.22 Corporate Stability	3.3
CF.20 Appropriate Methodology for Project Management	4.1	CF.35 Long-term Perspective	3.7	*CF.37 Researchers Interactions with Industry Partner	3.3
CF.39 Balanced Benefits Realisation	4.0	*CF.38 Political Support and Funding	3.6	CF.27 Previous Collaborations and Experience	3.2
CF.41 High Motivation	4.0	CF.17 Adequate Budgeting	3.6	*CF.24 Appreciating Different Viewpoints	3.1

* Removed Critical Success Factors

The CSFs were further analysed regarding their importance during the UIC's lifecycle [23]. The generally acknowledged terminology of 'pre-award' and 'post-award' phases was used to describe the difference between proposing and executing a project [39]. A 'transitional' phase between these two phases was also included. The 'transitional' phase occurs before formalising the funding contract. During this phase, the collaboration participants also start negotiations on the governance structure and the roles and responsibilities of each participant during project execution and delivery ('post-award' phase) [40]. The 'transitional' phase corresponds to the handover of the planned project (pre-award) once it has received formal approval to the actual project management team (post-award) [33].

The relevance of each CSFs to each of the UIC lifecycle phases was analysed, also taking into account their classification as 'human', 'technical' or 'organisational' factors. The results are presented in Table 3 and some key observations include:

- The 'pre-award' phase includes the most significant number of CSFs, followed by the 'post-award' phase and the 'transitional' phase.
- More 'technical' CSFs considered relevant to the 'pre-award' and 'post-award' phases than the 'transitional' ones.
- The 'organisational' CSFs are considered more relevant to the 'pre-award' phase, followed by the 'post-award' and 'transitional' phases.
- In the 'pre-award' phase, the 'human' and 'organisational' CSFs are equally relevant to a lesser extent than the 'technical' CSFs.
- In the 'transitional' phase, the most relevant CSFs are the 'human' factors, followed by the 'technical' factors and, to a lesser extent, by the 'organisational' CSFs.
- In the 'post-award' phase, the 'technical' factors are dominant and the 'organisational' factors the least relevant of the three categories considered.

Table 3. Most important critical success factors throughout the UIC lifecycle.

Category	Pre (23)	Trans (13)	Post (21)	Critical Success Factors
Technical (17)	CF.02			Clear and Realistic Goals
	CF.03		CF.03	Mutually Agreed and Updated Work Plan and Deliverables
	CF.04	CF.04	CF.04	Effective Communication
	CF.06		CF.06	Qualified and Skilled Teams
			CF.08	Effective Change Management
	CF.09	CF.09	CF.09	Competent Project Managers
	CF.11			Clearly Allocated Resources
	CF.13			Realistic Schedules
			CF.14	Risk Management
			CF.16	Regular Monitoring & Control
	CF.17			Adequate Budgeting
			CF.19	Effective External Subcontractors
		CF.20		Appropriate Methodology for Project Management
		CF.23		Learning and Benchmarking
		CF.26		Clear Roles and Responsibilities
	CF.29			Complementary Expertise
			CF.40	Training Provision
Human (7)	CF.05	CF.05	CF.05	Stakeholder Engagement
	CF.12	CF.12	CF.12	Good Leadership
	CF.15	CF.15	CF.15	Collaboration Champions
	CF.25	CF.25	CF.25	Mutual Trust and Respect
	CF.28		CF.28	Teamwork
	CF.41	CF.41	CF.41	High Motivation
	CF.42	CF.42	CF.42	Effective Conflict Management
Organisational (10)	CF.01		CF.01	Senior Management Commitment
	CF.10			Shared Vision and Goals
			CF.18	Adaptive Cultures
		CF.21	CF.21	Good Governance
	CF.22			Corporate Stability
	CF.27	CF.27	CF.27	Previous Collaborations and Experience
	CF.31			Mutual Benefits and Aligned with Partners' Strategy
	CF.32			Mutual Understanding of Partners' Needs
	CF.35			Long-term Perspective
			CF.39	Balanced Benefits Realisation

When the top eight CSFs between the university and industry participants are analysed, four belong to the ‘human’ factors, three to ‘technical’ factors and only one to the ‘organisational’ factor. It can also be observed that half of the CSFs are common to the three phases, seven with the ‘pre-award’ phase, six with the ‘post-award’ phase and four with the 'transitional' phase. This provides further evidence about the varying relevance and importance of these CSFs over the complete lifecycle of UICs. To emphasise this, Plewa et al. [28], with a more limited number of CSFs, also identified the relevance of CSFs throughout project phases. The trust CSF for example is important through the whole project lifecycle, but at varying degrees. In the 'pre-award' phase, trust is a necessary CSF in reputation and credibility. In the 'transitional' phase trust is essential in the individual. In the 'post-award' phase trust is critical in relationships.

5. Conclusions

This research has focussed on varying levels of importance of CSFs during the key stages of a UIC lifecycle. An initial literature survey identified forty-two CSFs for managing UICs successfully. These CSFs have varying importance depending on what they impact i.e., 'human', 'technical' or 'organisational' and during which phase of the UIC lifecycle i.e., 'pre-award', 'transitional', and 'post-award'. Judgements made by key university researchers and industry practitioners of one major UIC case study were used to classify and validate each CSF according to their impact on the effectiveness of the UIC and their importance during the UIC's lifecycle. The top eight CSFs identified are: Senior management commitment; Effective communication; Stakeholder engagement; Good leadership; Clear & realistic goals; Mutual trust and respect; Teamwork and Clear roles and responsibilities. Additionally, we can conclude that the 'pre-award' phase includes the most significant number of CSFs (23), followed by the 'post-award' phase (21) and the 'transitional' phase (13). Moreover, the analysis helped to identify overlaps between CSFs.

Our research results were limited to the use of a single case study albeit in a very large and prolonged UIC consortium. Future research will need to include a broader survey of academics and industry professionals involved in multiple collaborative R&D projects. Additionally, this research was limited to the analysis of CSFs related to management and governance issues of UICs, excluding contextual CSFs, such as geographic distance [24].

A significant criticism of the success factor approach [23] concerns the lack of analysis of the inter-relationships between factors. To address these issues, future research will be conducted using interpretive structural modelling [41] to understand the contextual relationship among the CSFs and extract the root factors for the success of UICs. Interpretive structural modelling develops a hierarchical structure for analysing the interactions among CSFs.

In conclusion, this research has gone beyond generic-oriented evidence and details specific practice-oriented factors. This facilitates the development of strategies and plans to ensure the fulfilment of essential CSFs thus, increasing the odds of attaining a successful project.

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