Vol. 11 | No. 3 | 2023

International Journal of Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

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International Journal of Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X

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The mission of the IJISPM - International Journal of Information Systems and Project Management - is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

The journal serves academics, practitioners, chief information officers, project managers, consultants, and senior executives of organizations, establishing an effective communication channel between them.

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The IJISPM offers wide-ranging and comprehensive coverage of all aspects of information systems management and project management, seeking contributions that build on established lines of work, as well as on new research streams. Particularly pursuing multidisciplinary and interdisciplinary perspectives, and focusing on currently emerging issues, the journal welcomes both pure and applied research that impacts theory and practice.

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Authors are encouraged to submit articles on information technology governance, information systems planning, information systems design and implementation, information technology outsourcing, project environment, project management life-cycle, project management knowledge areas, criteria and factors for success, social aspects, chief information officer role, chief information officer skills, project manager role, project manager skills, among others.

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- project execution
- project control and monitoring
- project closing
- success criteria and success factors
- project manager role
- project manager skills
- portfolio management
- program management
- managing organization - structure
- tools and techniques
- project evaluation
- success management
- project management knowledge areas
- scope management
- time management
- cost management
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Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the third number of the 11 volume of IJISPM. In this issue readers will find important contributions on PMO, AI projects, R&D project management and DevOps.

The first article, "Using the PMO to enforce and standardize the attention of software project managers to needs of software project teams", is authored by Robert Hans and Ernest Mnkandl. Software project teams (SPTs) are critical stakeholders. However, the empirical evidence of their importance seems to exist on paper only, as software project managers (SPMs) and scholars in the project management field ignore their individual needs, and as a result, SPTs remain the most neglected stakeholder group in the software industry. In endeavouring to address the neglect of SPTs, the authors of this study developed a model aimed at assisting SPMs to pay due consideration to the needs of this important stakeholder group. At the heart of the model's functionality is the Project Management Office (PMO), which intends to enforce and standardize the gathering and addressing of software project team needs and interests by SPMs. The aim of the research study is to investigate how the functions of the PMO can be applied to operationalize the enforcement and standardization of the overall function of the model.

The title of the second article is "Failure factors of AI projects: results from expert interviews", which is authored by Dennis Schlegel, Kajetan Schuler and Jens Westenberger. In the last few years, business firms have substantially invested into the artificial intelligence (AI) technology. However, according to several studies, a significant percentage of AI projects fail or do not deliver business value. Due to the specific characteristics of AI projects, the existing body of knowledge about success and failure of Information Systems (IS) projects in general may not be transferrable to the context of AI. Therefore, the objective of this article is to identify factors that can lead to AI project failure. Based on interviews with AI experts, this article identifies and discusses 12 factors that can lead to project failure. The factors can be further classified into five categories: unrealistic expectations, use case related issues, organizational constraints, lack of key resources, and, technological issues.

The third article, authored by Katharina Dieterich and Peter Ohlhausen, is entitled "CLIPS: Enriching interorganizational R&D project management by a project culture focus". According to the authors, project managers still face management problems in interorganizational Research and Development (R&D) projects due to their limited authority. Addressing a project culture which is conducive to cooperation and innovation in interorganizational R&D project management demands commitment of individual project members and thus balances this limited authority. However, the relational collaboration level at which project culture manifests itself is not addressed by current project management approaches, or it is addressed only at a late stage. Consequently, project culture develops within a predefined framework of project organization and organized contents and thus is not actively targeted. Therefore, a focus shift towards project culture becomes necessary. This can be done by a project-culture-aware management. The goal of this paper is to demonstrate the integrability of the method CLIPS and show how it can be integrated in common project management approaches.

"Critical success factors for DevOps adoption in information systems development" is the fourth article and is authored by Vihara Jayakody and Janaka Wijayanayake. Adopting DevOps is challenging since it makes a significant paradigm shift in the Information Systems (IS) development process. DevOps is a trending approach attached to the Agile Software Development Methodology, which facilitates adaptation to the customers' rapidly-changing requirements. However, software development companies reported challenges in adopting DevOps. It is critical to control those challenges while getting hold of the benefits by studying Critical Success Factors (CSF) for adopting DevOps. This study aimed to analyse the use of DevOps approach in IS developments by exploring CSFs of DevOps. A systematic literature review was applied to identify CSFs. These factors were confirmed by interviewing DevOps practitioners while identifying more frequent CSFs in the software development industry. The authors present a conceptual model for CSFs of DevOps, which is a guide to reap the DevOps benefits while reducing the hurdles for enhancing the success of IS. The conceptual model presents CSFs of DevOps, grouping them into four areas: collaborative culture, DevOps practices, proficient DevOps team, and Metrics & Measurement.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Guest Editors,

Dulce Domingos, *University of Lisbon, Portugal*

Ricardo Martinho, *Polytechnic Institute of Leiria, Portugal*

Dulce Domingos received the BSc in "Informática" from Faculdade de Ciências da Universidade de Lisboa, Portugal, in 1993, the MSc degree in "Engenharia Electrotécnica e de Computadores" from Instituto Superior Técnico da Universidade Técnica de Lisboa, Portugal, in 1997, and the PhD degree in “Informática" from Faculdade de Ciências da Universidade de Lisboa, Portugal, in 2005. She is a professor at the Departamento de Informática, Faculdade de Ciências, Universidade de Lisboa and researcher of the Large Scale Computer Systems Laboratory (LaSIGE). Her current research interests include security, business processes, and Internet of Things (IoT). She is the coordinator of the master program in information security of Faculdade de Ciências, Universidade de Lisboa and Pró-rector at Universidade de Lisboa.

Ricardo Martinho is an Associate Professor at Polytechnic of Leiria, Portugal. He teaches several subjects related to enterprise information systems, enterprise application development, software engineering (agile methods) and healthcare computer programming and information systems. He graduated in Electrical Engineering - Computer Science at University of Coimbra, received his MSc in Computer Science - Information Systems Programming from IST - Technical University of Lisbon, and his PhD from University of Trás-os-Montes and Alto Douro. He is also a Researcher at the Center for Health Technology and Services Research (CINTESIS), and at INESC Coimbra. He has more than 90 publications in journals, books and conference proceedings related to Software Engineering, Business Process Management, Process Mining and Health Informatics. He serves as executive editor, member of editorial board and reviewer for several books and international journals, and has served in several committees of international conferences. He is a co-founder of HCist - International Conference on Health and Social Care Information Systems and Technologies.

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Using the PMO to enforce and standardize the attention of software project managers to needs of software project teams

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Robert Hans, Ernest Mnkandla, “Using the PMO to enforce and standardize the attention of software project managers to needs of software project teams”, *International Journal of Information Systems and Project Management*, vol. 11, no. 3, pp. 5-22, 2023.

International Journal of
Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X

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Abstract:
Software project teams (SPTs) are critical stakeholders. Their contribution in successful delivery of software projects is unquestionable. However, the empirical evidence of their importance seems to exist on paper only, as software project managers (SPMs) and scholars in the project management field ignore their individual needs, and as a result, SPTs remain the most neglected stakeholder group in the software industry. In endeavoring to address the neglect of SPTs by SPMs, the authors of this study developed a model aimed at assisting SPMs to pay due consideration to the needs of this important stakeholder group. At the heart of the model's functionality is the Project Management Office (PMO), which intends to enforce and standardize the gathering and addressing of software project team needs and interests by SPMs. The aim of the research study is to investigate how the functions of the PMO can be applied to operationalize the enforcement and standardization of the overall function of the model. Since the study is practical-oriented, the pragmatic interpretive approach was considered a suitable methodology. Through the interpretative methodology, several appropriate functions of the PMO, such as «Project management methodology, standards, and tooling», «Monitoring and controlling project performance», «Human resource management» and «Development of project management competencies» as established from project management literature were utilized to achieve the study's purpose. Even though the interpretation process was guided by literature, the inference was also influenced, to a certain extent, by the researcher opinion as «interested observer». Therefore, the approach presents a limitation to the study. Future studies should include the validation of the feasibility of the study's claim in a real-world project setup.

Keywords:
software project; project management office; project team; project manager; enforcement; standardization.

DOI: 10.12821/ijispm110301

Manuscript received: 25 March 2022
Manuscript accepted: 21 December 2022

1. Introduction

Software project teams (SPTs) are indispensable stakeholder groups in software development projects. The SPTs that are of interest in this study include software developers, software testers, system analysts, software architects, and database designers which are directly involved with software development activities. SPTs are fundamental to software development projects [1], [2] and the success of software projects is almost entirely dependent on SPTs [3], [4], thus without them there would be no projects to speak of in the software industry. The assertion made by Cooke-Davies [5] that '*it is people who deliver projects, not processes and systems*' probably holds true for the software development industry than any other industry. The view of software development being more human dependent is also supported by Lu et al. [2], who claim that the development of software is a more human effort than a technological one. However, project teams (SPTs included, because Bourne [6] solely used software project case studies in her cited work here) are often not considered important project stakeholders by management [6]. Furthermore, the neglect of some of the software project stakeholders, SPTs included, has led to project failures in the industry [7]. SPTs are the most neglected stakeholder group by many software project managers (SPMs) [8], project stakeholder management researchers [9] as well as other researchers on project success and project team management [10]. Despite the benefits of considering project team member input in key project decisions [11], Hans [8] established that the views and interests of SPT members are often not given due consideration by SPMs. One plausible reason for the neglect of this important stakeholder group is that they are perceived as possessing little economic power, as alluded to by Eskerod et al. [12] as well as Hans and Mnkandla [13]. However, Eskerod et al. [14] bemoan the side-lining of certain project stakeholders based on their economic power or any other attributes, advocating instead for equitable treatment of all stakeholders, irrespective of economic power or other attributes.

In attempting to address the poor treatment of SPTs by software project managers, the authors of this research study developed a model (in a separate study, see [8] for a detailed discussion of the model, which will henceforth be referred to as the original study). The purpose of the model is to assist SPMs to pay due attention to the needs and interests of SPTs, and thus treat them as key project stakeholders. One of the important findings of the original study was the varying attention allocated to software project team needs by SPMs, with some attending to team needs while others ignoring them. The same study also found that the processes for soliciting views and concerns of SPTs were undocumented, and therefore open to various interpretations and inconsistent implementation by SPMs. Central to the model's function is the use of the project management office (PMO) (see Fig. 1 in Section 2) to enforce and standardize the collection of SPT member project interests [8] by SPMs, so that the practice is sustained and embedded in organizational culture. Furthermore, the inclusion of the PMO in the model ensures standardized, consistent, and uniform attendance to SPT needs by SPMs in an organization. The use of the PMO for standardization of this project management practice, namely, the collection and addressing of SPT views and needs, is in accordance with Silvius's [15] assertion that the PMO is best suitable for such a function. The importance of standardization of project management practices has been deemed a significant issue in the information and communication sector by Fernandes and Araújo [16]. Moreover, enforced standards (standardized processes in the context of this study) offer various benefits in an information technology environment [17].

There is general consensus that a project management office is crucial for successful and efficient delivery of projects [18]. Dai and Wells [19] agree with this claim by stating that a PMO enables project management effectiveness through lessons learned which emanate from project success or project failure perspectives. A PMO is tasked with overseeing the implementation, standardization, and enforcement of project management practices within an organization [20], [21]. A study by Hobbs further established that a PMO's second most important function is the development and implementation of standardized project management practices [22]. Project management practices enable organizations to achieve strategic objectives and improve project value [23], while through standardized project management practices, organizations realize synergies and best practices [24]. Over and above the aforementioned functions, a PMO supports and controls project activities [25]. One such project activity is team management [24], which includes addressing project concerns and needs.

The preceding discussion outlined various expectations of a PMO to promote and instill best project management practices within an organization. Leveraging on these possibilities, this study intends to explore how the PMO may be utilized to operationalize the enforcement, standardization, or institutionalization of the implementation of the model's overall function, which is to assist SPMs to solicit and address SPT views and concerns. The research questions (RQs) the study aims to address are as follows:

***RQ** 1: How can the PMO be used to enforce the overall function of the model?*

***RQ** 2: How can the PMO be used to standardize the overall function of the model?*

The remainder of the paper is structured as follows. The next section presents the background of this study, including a brief description of the model. The research approach used by this paper is presented in Section 3, while Section 4 discusses the functions and roles of the PMO to achieve this study's objective, namely, to enforce and standardize the model's implementation within an organization. Lastly, Section 5 presents the conclusions, limitations, and possible future work.

2. Background

This section discusses software project stakeholders, which include software project teams (SPTs). It highlights the neglect of SPTs despite recognition as key project stakeholders. The needs of SPTs and the importance of considering these needs are presented alongside an explanation of the historic neglect of software project teams and previous attempts to address this neglect, including the model developed by the authors of this study for intervention. This section also discusses various broad PMO functions which are meant to facilitate the implementation, enforcement and standardization of project management practices in an organization.

2.1 Software project stakeholders

As with projects in other industries, software projects require collaboration of various stakeholder groups, including project clients, project sponsors, and software teams. A common and generic acceptable definition of *project stakeholder* is '*an individual, group, or organization that may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project, program, or portfolio*' [21, p723]. As this definition confirms, project stakeholders may affect (positively or negatively) project outcome. It is on this basis, amongst other factors, that stakeholders are recognized as important and their management by project managers is crucial for project success. Freeman et al. [27] concur, expressing that business managers (SPMs in our context) should pay requisite attention to (project) stakeholders.

Beside the fact that project stakeholders may *affect* a project, they may also *be affected* by the project or project outcome, and therefore they have certain expectations and needs that should be met through the project or project activities [28]. The idea of 'benefiting' between a project and its stakeholders should be reciprocal and mutual. The needs of SPTs include recognition, training, career advancement opportunities, a conducive work environment, and participation in SPM decision-making processes [29], [30]. Software project teams expect SPMs to be aware and address these needs and expectations, because SPT members feel valued when their needs are attended to [31]. In particular, a team leader who encourages participative decision-making within a team empowers the team members; this, in return, enhances team performance [32]. Furthermore, better managed knowledgeable workers, such as (software) project teams, increase an organization's competitiveness in its industry [33]. Even so, Laplante [34] concedes, proper management of software teams has proven to be an Achilles' heel of SPMs.

2.2 Software project teams as neglected key stakeholders

The discussion in the previous section highlighted the necessity for SPMs to pay undivided attention to key project stakeholders. Amongst the key software project stakeholder groups that need special attention are software project teams. The reason for SPMs to pay particular attention to SPTs is because software projects are virtually and totally dependent on SPTs for success, as alluded to by André et al. [35] and McLeod et al. [28]. Without software project teams, successful delivery of projects is nearly impossible [36]. SPTs are the foundational units through which software project tasks are accomplished and delivered [32].

With the plethora of empirical evidence of the key role played by SPTs in projects, their neglect at the hands of certain project managers is not only unfortunate but has impaired organizations and hindered projects. Some negative results that emanate from the neglect are discussed by Hans and Mnkandla [37], Mainardes et al. [38], and Pee et al. [39]. A recent study by Hans [8] confirmed that the views and interests of SPTs do not receive due attention from some software project managers. Another recent study by Tanveer [40] argues for more empirical research on software engineers' needs (research on how the needs and interests of software team members can be addressed). These research studies by Hans [8] and Tanveer [40] confirm the neglect of SPTs by both SPMs and researchers in the software development field respectively. The findings by Hans [8] do not come as a surprise based on the findings of a study by Paradise [41] that managers, in general, are not capacitated to deal with employee needs. Furthermore, the inability of managers, SPMs included, to engage with their teams directly contradicts what the twenty-first century employee requires: continuous engagement with a line manager, as claimed by Lee et al. [42].

2.2.1 Related work: models and tools aimed at addressing needs of project stakeholders

Several stakeholder management models aimed at assisting project managers to better manage project stakeholders and give the necessary attention to project team interests have been proposed and developed by various researchers. The Stakeholder Circle methodology [43], [44] and the Social Network Analysis (SNA) approach [45] are two notable stakeholder management models popular in the project management field.

The aim of the Stakeholder Circle methodology was to provide project teams with capabilities to identify, prioritize stakeholders, develop and manage relationships with key stakeholders. Despite the model's contribution to improving stakeholder management, the tool has the following limitations: (i) The tool was not tested/evaluated on full project life cycles on any of the five projects used for its evaluation – its effectiveness is based on one phase of each project [43]. Therefore, the effectiveness of the model across different project phases is unknown; (ii) The Stakeholder Circle methodology classifies project stakeholders based on their attributes, namely, power (influence), urgency (determination for immediate attention) and legitimacy (right/claim/authority) [45]. The classification of stakeholders using this approach may lead to marginalization of certain project stakeholders (while '*selling the project to the most important stakeholders*' [46]) and/or misclassification of influential project stakeholders as having less project influence and legitimacy, for example. Moreover, the attributes possessed by project teams should not be a determinant of the treatment or non-treatment of their needs by project managers [47] – the needs of all stakeholders should receive attention of project managers.

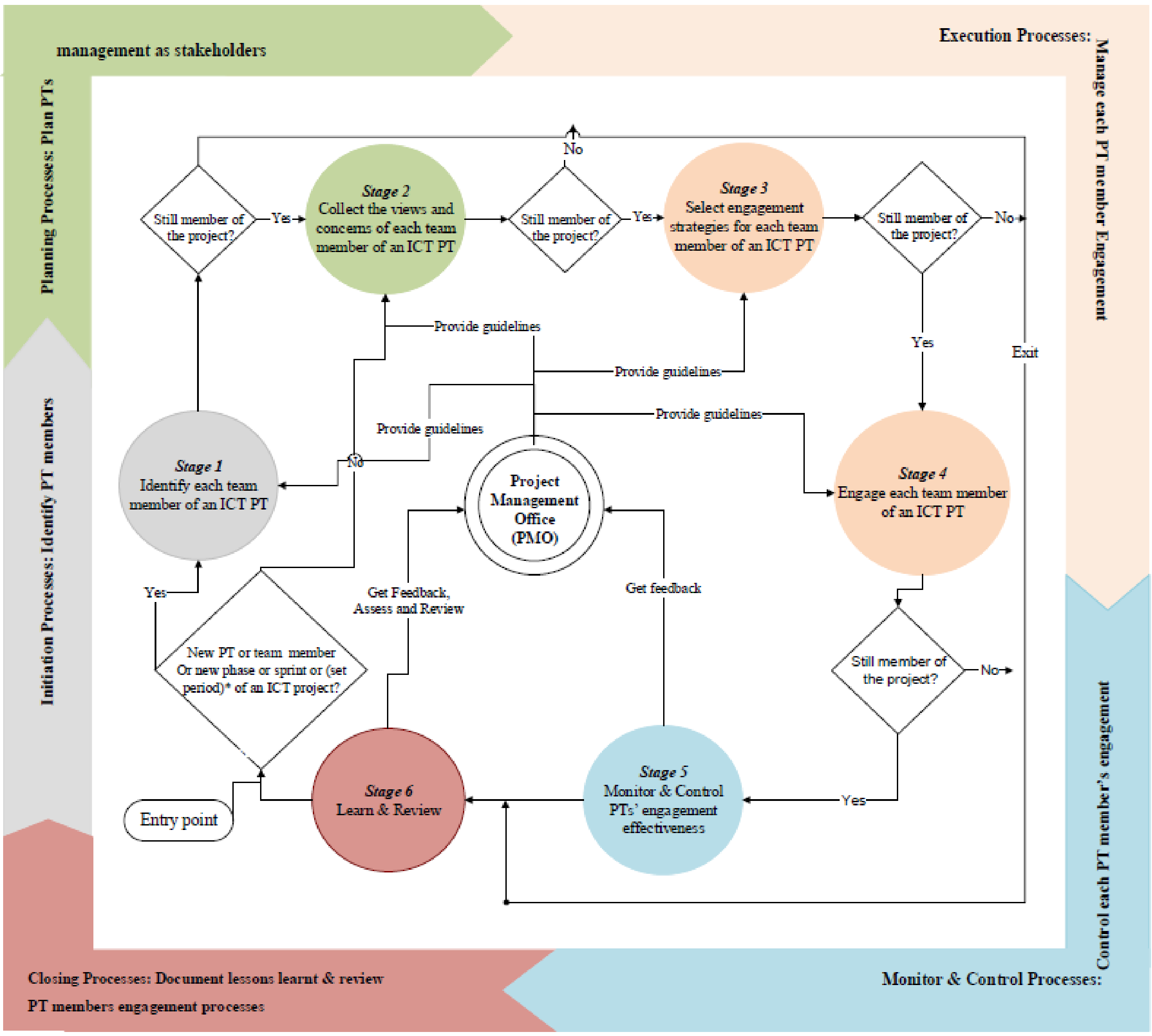
The purpose of the SNA model was to enable project managers to examine the whole structure of project stakeholders (rather than individual stakeholders) together with impacts of stakeholders, with the aim of better understanding the existence of inter-relationships between the network of stakeholders, an organization and projects. The SNA model '*enhances understanding of the project environment as a network of relationships within and around the project organisation*' [43]. The model allows a project manager to use 'known' stakeholders to identify other 'unknown/hidden' stakeholders. Even so, the SNA model presents the following major limitations: practical and ethical difficulties become an issue during the process of collecting information from stakeholders about other stakeholders (i.e. using the snowballing process) in terms of the confidentiality of the required data [45].

The abovementioned models have not yielded the desired results in terms of addressing the neglect of software project teams by project managers [8]. This led to the authors of this study to propose and develop a model aimed at addressing this neglect, see Fig. 1. Besides the shortcoming of the aforementioned models and frameworks to address the neglect of SPTs by SPMs as mentioned in the preceding paragraph, another major weakness of these models is the failure to enforce and standardize their implementation within projects and across an organization. The model in Fig. 1 uses a PMO to address and overcome this weakness. This study contributes to the body of knowledge by demonstrating how the PMO can be used to enforce and standardize a stakeholder management model. The next section provides an overview of this model.

This study is not the only one to have applied the functions of the PMO to achieve certain organizational or project management related objectives. A recent study by Silvius [15] also used the PMO to outlined how this office may enhance the sustainability of projects and project management.

2.3 *Brief overview of the model*

Fig. 1 depicts the model whose implementation this study seeks to enforce and standardize through the use of PMO functions. The following discussion summarizes the six important phases of the model for SPMs to follow. The stage designated as entry point is where the model's processes begin, typically at the start of a project or at the beginning of a new project phase or sprint. Once this step has been ascertained, Stage 1 of the model would follow.



Set period* - is any iterative period set by the PMO in conjunction with a project manager / scrum-master to start / continue the process of the model.

Fig. 1. A model for assisting SPMs to treat SPTs as key stakeholders (Adapted from Hans [8])

Stage 1: Identify each member of the information and communication technology software project team – At this stage every software project team member who is a stakeholder at the current project phase or sprint is identified by an SPM or Scrum master. The identification process of SPT members requires that the needs and interests of each identified individual team member be established.

Stage 2: Select engagement strategies for each identified team member – During this stage, an SPM or Scrum master is expected to identify and select suitable engagement strategies for each identified individual team member. Since team members are unique (with differing personalities and preferred communication methods), it is important that an SPM or Scrum master personalize engagement strategies to improve communication between the SPM or Scrum master and the concerned SPT member. The need to personalize engagement strategies according to individual team members is in line with Laplante's [34] postulation of treating software team members as unique individuals because their needs and personalities are different.

Stage 3: Collect the views and concerns of each team member – This stage requires that views and concerns pertaining to the project are solicited from each software project team member using the engagement strategies identified in Stage 2.

Stage 4: Engage each team member of the project on the collected views and concerns – Once the views and concerns of each SPT member have been gathered and analyzed, an SPM needs to engage individual team members on their needs with the specific aim of addressing these needs.

Stage 5: Monitor and control the project manager-project team engagement process – During this stage, the PMO of the organization gathers and assesses feedback from SPMs and their SPT members on the effectiveness of the SPM-SPT engagement process, with the aim of improving the SPM-SPT engagement process where necessary.

Stage 6: Learn and review – During this step, the PMO evaluates the input of SPMs and their SPT members, as indicated in Stage 5, to identify lessons learned and review the process and guidelines regarding the effectiveness of the SPM-SPT engagement process. The lessons learned are to be documented for future use and reference purposes.

2.4 Standardization and enforcement of project management practices

Many organizations from different sectors use projects to remain competitive and achieve their goals [25]. This typically results in the operation of many interdependent projects within an organization at any given time. Likewise, organizations rely on project management for efficient running of projects [48] and to increase productivity [49]. The interdependency among projects within an organization and the intention to smoothen such synergies has led organizations to seek ways to standardize their project management practices. In this paper, *standardized project management practice* refers to the level of uniformity or consistency applied in carrying out project management processes, as defined by Milosevic and Patanakul [50]. Standardization of project management processes improves operations, reduces process errors, and promotes expert knowledge sharing [51]. On the other hand, non-standardization of project management of project management practices may result in inconsistent project outcomes [52]. Standardized project management practices constitute what Beck [53] refers to as 'foundation practices', the organization's project management pillars. The information and technology sector values the standardization of project management processes, tools, and techniques as more important than other sectors do [16] and use standardized project management practices as strategic tools for managing projects [50]. Moreover, standardization of project management practices has brought many positive outcomes (e.g., simplified project management and assessment [53]) and has provided organizations with high performing value-adding project management systems. Aligned or interrelated projects can be managed seamlessly as a portfolio of investment [25] and thereby improve their return on investment and reduce project costs [54] through standardized project management practices. This assertion is supported by Mueller et al. [55], who explain that standardization of information technology processes reduces complexity and costs related to information technology, while the absence of well-documented standardized processes results in confusion and uncertainty [17].

Standardization of project management practice is necessary but not sufficient – an organization needs to enforce the foundation practices to achieve the desired results [56]. Steinfield et al. [57] corroborate this by reaffirming: '*process* *standards are necessary, but not sufficient.*' Successful implementation of standardized project management practices may only be realized in an organization when practices are enforced by top management through a PMO [58]. However, Mueller et al. [55] warn that enforcement of standardized practices without employee buy-in for these practices is unlikely to be successful.

Organizations seem to lack mechanisms for characterizing and governing their process standards [17] and this supports similar claims by Bolles and Hubbard [59] that organizations have found it challenging to apply the same project management practices consistently and uniformly across their business units. The Project Management Institute (PMI) also confirms that several organizations have no consistent procedures to govern projects [60]. Kezner [61], though, reiterates the centrality of PMOs to the standardization of project management operations and practices: a PMO enables the realization of common and organization-wide project management practices. Furthermore, according to Hobbs and Aubry [62], a PMO assists in providing the oversite function of monitoring and controlling project management practices. Silvius [15] likewise confirms that a PMO has several responsibilities, some of which are listed in Table 1. The functions range from simple supportive functions (e.g., functions under *Project support and archiving responsibility*) to enforcing compliance (e.g., *develop and implement a standard methodology*). Project managers are expected to run projects in accordance with the organization's (project management) practices and procedures [21], typically made possible by use of the PMO. A recent study by Hans and Mnkandla [20] suggests that it is almost impossible to standardize project management practices and processes within an organization without making use of a PMO. A word of caution however: in as much as organizations should strive for standardization of project management practices, they must avoid over-standardizing as one size does not fit all in project management [63].

Table 1. PMO responsibilities (Adapted from Hobbs and Aubry [62] as well as Silvius [15])

Responsibility	**Possible task**
Project management methodology, standards, and tooling	Develop or select a methodology for project management processes and methods Provide a set of PM tools
Monitoring and controlling project performance	Monitor and control project performance Develop and maintain a project scoreboard
Benefits realization management	Benefits management Conduct post-project reviews
Human resource management	Human resource and staffing assistance Recruit, select, evaluate, and determine salaries for project managers
Development of project management competencies	Provide mentoring for project managers Provide trainings and/or certifications for project managers Provide trainings and/or certifications for other project personnel
Project support and archiving	Manage archives of project documentation Provide a set of tools without an effort to standardize
Promote project management within organization	Project management consulting Promotion of project management practices within the organization
Organizational learning	Conduct project audits Implement and manage a database of lessons learned

3. Research methodology

Since the study's aim is to establish *how* the PMO can be utilized to enforce and standardize the implementation of the model, then the research methodology followed in this paper is a pragmatic and interpretive one. Interpretive research methodology is suitable for research studies, which intend to answer *how* questions [64]. Mackenzie and Knipe [65] as well as Walsham [66] also confirm the suitability of an interpretivism approach for Information Systems (IS) research. Several researchers such as Boland and Day [67], Curtis et al. [63], and Schneiderman and Carrol [69], for example, have used the interpretive approach in the IS field. Furthermore, Silva et al. [70] assert that pragmatism is a research approach which considers data from a practical perspective and thus is appropriate for IS research too. Again, since the study is practical-oriented, a pragmatic interpretive approach was deemed suitable [15], [71]. As pragmatism is oriented towards solving real world practical problems [72], then it was used to derive the necessary knowledge on how the PMO can be used to enforce and standardize the implementation of the model.

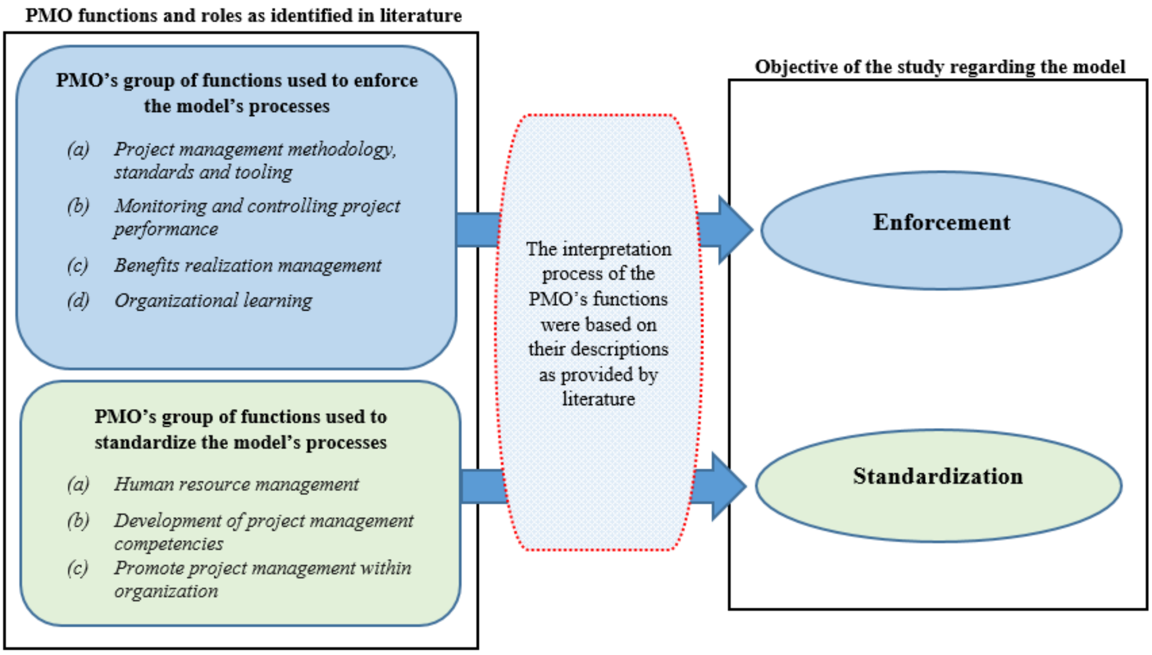


Fig. 2. Interpretive process followed in achieving the aim of the study

Interpretive approach was judiciously and creatively utilized (as interpretivism promotes creativity [70]) on several suitable functions of the PMO as found in project management literature to indicate how PMO roles may be applied to achieve the objectives of this research. Fig. 2 provides a high-level view of the interpretive process followed by this study and which PMO functions or roles were used for the enforcement and standardization of the model's implementation. The study employed the interpretive description to outline how relevant PMO functions may be used to enforce and standardize the adoption of the model across an organization. In achieving this objective, the researchers based their interpretation on human sense guided by meanings/definitions/description [73] of the PMO functions as informed by relevant literature. For example, *Monitoring and controlling project performance* is one of the PMO group of functions identified in literature (see Table 1) that this study used to enforce the model's processes. One of the associated tasks that define this function is monitoring and control of project performance, which includes assessing compliance and adherence and taking corrective actions, where necessary, regarding stakeholder engagement (SPMs-SPTs engagement in the context of this paper) as a project management practice and process [74]. Since the study's model requires SPMs to constantly and consistently engage with their SPTs in order to address their project needs and expectations, the use of *Monitoring and controlling project performance* function of the PMO (based on the functions' description/definition) to achieve this purpose is therefore a logical interpretation. Monitoring, controlling, and evaluation of adherence to the established SPM-SPT engagement processes will assist in enforcing this important practice within and across projects in the organization. The description/definition of the function further assisted in determining whether the function should be used for enforcement or standardization purposes of the model's implementation. For example, the monitoring and control task is meant for assessing progress against stated project objectives, with the aim of ensuring that responsible people are held accountable for their performance and where necessary effect improvement on related activities and practices [75]. The need for accountability requires that project stakeholders comply with the set project objectives, practices and processes. Therefore, the function's elaborate description given here fits the enforcement need of the model's implementation.

4. Enforcement and standardization of the model's implementation using the PMO

The discussion presented in this section concerns how the functions and roles of the PMO as identified in literature were applied in achieving the intended enforcement and standardization of the model. On issues of project management practices, this study considers the PMO as an agent of change, as proclaimed by Yornu and Ackah [76]. The need for the enforcement of the model's functionality emanates from the original study's findings, which revealed the following [36]:

- Some organizations had not established processes to assist SPMs in eliciting project-related views and concerns of their team members;
- In organizations with processes, implementation and observation depended on the will of SPMs, with some following the processes while others not. In other words, there were no uniform or consistent adherence to processes aimed at collecting SPT views and concerns, a situation potentially linked to the lack of documented and standardized processes [20].

The aim of the model was to assist SPMs to gather views and concerns of project team members effectively and efficiently. The inclusion of the PMO as part of the model is intended to address the inconsistent implementation of the model in an organization. Table 1 shows various functions associated with the project management office. The discussion in the following sections on PMO group of functions presents an argument on how these functions may be used to enforce and standardize the processes of the model.

4.1 Enforcement of the model's processes

Subsections 4.1.1, 4.1.2, 4.1.3 and 4.1.4 discuss how '*Project management methodology, standards, and tooling,' 'Monitoring and controlling project performance'*, '*Benefits realization management*' and '*Organizational learning*' functions may be used to institute and enforce the model's function.

4.1.1 Project management methodology, standards, and tooling

One of the key roles of the PMO is the creation and enactment of standardized project management methods, processes, and other practices [62]. The lack of processes or undocumented or non-standardized processes to elicit SPT views and concerns may contribute to the poor attention of SPMs to team member concerns and needs, as alluded to by Hans and Mnkandla [20]. Moreover, an absence of documented processes breeds uncertainty among employees (SPMs), as they may not know why a particular process exists or how to apply it [17]. But SPMs cannot be held accountable for failure to solicit their teams' views and concerns when there are no processes in place for assisting them to do so. This is so because project management processes, tools, and methodologies serve as a bedrock for other functions and roles of a PMO [77]. The PMO is an overseer of project management practices, and thus perfectly positioned for a mandate to institute, implement, foster, and proclaim the necessary processes to be adhered to by software project managers. The discussion on the model in Subsection 2.3 indicated the need for the PMO to decide – in conjunction with SPMs – the model's entry point as well as the opportune time to execute the different phases of the model. Furthermore, the PMO should establish necessary templates to be used by SPMs and SPTs for input and comments to the PMO about their consultative activities. At the end, the PMO is expected to produce well-documented processes and guidelines to which SPMs and SPTs are expected to adhere in the application of the model.

4.1.2 Monitoring and controlling project performance

Hobbs and Aubry [62] consider the monitoring and controlling function of the PMO as the most significant of all PMO functions because it directly supports project governance and enables control of project activities [78]. However, it is impossible to keep tabs on something that cannot be measured [79]. For the PMO to foster and control the adherence of SPMs to the established engagement processes, the effectiveness of these processes and the overall contentment of the affected parties should be ascertained and evaluated. The purpose of process evaluation is to determine the efficacy of the selected engagement strategies with the intention of improving them if need be. The monitoring, controlling, and evaluation of adherence to the established SPM-SPT engagement processes will be a signal that organization management values such processes. Measuring project processes demonstrates the value of such processes and promotes project visibility [80]. Rewarding the SPMs for their observance of the established processes will not only signal the importance of adhering to such, but will simultaneously promote and encourage the intended behavior and compliance [81], [82] of following the processes. A PMO should use its vested powers to persuade all SPMs to consider standardized or institutionalized project management practices, to pay due attention to SPTs interests and needs.

4.1.3 Benefits realization management

The PMI [83] defines *benefits realization* as an approach undertaken to derive benefits from the execution of tasks or projects. The overall purpose of the model designed by the authors of this study is to assist SPMs to focus on the needs and interests of software project team members. In reciprocity, SPT members will be loyal to the organization [84] and contribute to the success of the organization's projects [85]. Therefore, mutual benefits are realized in the implementation and enforcement of the model's function. It follows logically that the implementation and enforcement of the model's processes for the realization of its accrued benefits be carried out by the PMO through its benefits management function.

Conducting post-project reviews is another responsibility that falls under the benefits realization management function of the PMO, as indicated in Table 1. There are two types of project reviews, namely, the project performance measurement related review carried out during the project life span [5], and the project success measurement review (post-project review) undertaken at the completion of a project. The former review type is the one that is of interest to this study because the PMO's reviews of individual SPM adherence to SPM-SPT engagement processes as well as their compliance to the processes of the model happen during project execution. Knodel [54], however, contends that in certain organizations accountability for results is a foreign notion. Therefore, conducting project reviews is vital for holding accountable those responsible for project outcome and enabling an organization to learn from such project reviews, thereby improving project management practices. In the context of this paper, the review of SPM compliance to SPM-SPT engagement processes and the review of the individual SPM's level of observance to the model will enable the PMO to determine the level of compliance to the model's overall function by SPMs. Project review feedback will better direct the PMO in taking appropriate corrective actions, if necessary.

4.1.4 Organizational learning

Organizational learning is about preserving behaviors, values, mental models/maps and culture that define and characterize the organization [86]. In a bigger organization, projects are considered to be temporary organizations and sub-organizations [87], [88], and they are related to organizational culture [74]. It therefore follows that the behaviors, values and culture of the organization would be entrenched in its projects. After all, it is the aim of every organization to have all these (behaviors, values, mental models and culture) shared (assuming that its culture and values are good), perpetuated and entrenched into all its employees (including new employees) and its projects.

Therefore, through this group of functions the PMO as a custodian of project management practices and methodology is well positioned to disseminate project-related behaviors and values that should be shared across projects. Based on the preceding discussion, this study proposes the use of this group of functions to establish and promulgate the implementation of the model company-wide.

4.2 Standardization of the model's processes

The argument offered in Subsection 4.1.1 is equally relevant to this section on standardization of the model's processes, as presented in Fig. 1. This section discusses the use of '*Human resource management'*, *'Development of project management competencies'* and '*Promote project management within organization'* functions of the PMO for the standardization of model's processes, which include the gathering of the views and interests of SPTs that the model intends to operationalize organization-wide.

4.2.1 Human resource management

For an organization to apply a successfully proven common project delivery road map [74] and share best project management practices across the organization, the standardization of the project management practices and processes and efficient management of project teams is imperative. Attendance to SPT member project needs (a practice the model seeks to promote) is a human resource management practice that should be institutionalized and practiced by all SPMs in the organization. Project human resource management practices may not only be enforceable by the PMO, but may be standardized too [8] using the PMO human resource management function. The standardization would bring a desired outcome: consistent and common attendance to individual project team member needs and interests [50]. The positive side effect of the effective implementation of this PMO function is the reduction of key staff turnover or turnover intentions [84], [89], which is a desire of every organization.

4.2.2 Development of project management competencies

Organizations which regularly deliver successful projects have realized the importance of training, mentoring and developing new project leaders after their best project leaders [74]. The practice of growing project leaders has several advantages, including the instilling of common good project organizational culture into 'home-grown' project leaders that bolster the delivery of successful projects. Implementation of standardized mentoring and coaching programs for project managers ensures uniform training of mentees on project management practices, including consistent and unvarying attendance to SPT interests by SPMs. The PMO, as a guardian of good project management practices, has a unique opportunity to standardize such programs through its human resource training function.

4.2.3 Promote project management within organization

The PMO's functions may be classified as either operational (support to individual projects), tactical (managing coordination across multiple projects and promoting adoption of organizational project management practices) and strategic (prioritizing projects based on business objectives and strategy) [78]. At operational and tactical levels, the PMO may use functions under *Promote project management within organization* to support projects and ensuring that preferred project management practices and processes are adopted and applied. This approach could be used for standardizing and uniform adoption the desired project management practices across the organization. In the context of this study, the PMO can use these group of functions for company-wide implementation and standardization of the model. At a strategic level, on the other hand, the PMO may apply this group of functions to implement the model so as to address the needs and expectations of SPTs, resulting in a satisfied, committed, loyal and productive workforce, that is easy to retain [84]. Therefore, the use of these functions to promote the implementation of the model could result in multiple strategic benefits for an organization.

The preceding discussion in this section outlined how the PMO, through its various roles and functions, can be utilized to standardize and enforce the model's function in an organization. The ultimate goal is to engender a company-wide project team management culture which encourages SPM-SPT engagement that addresses SPT needs by SPMs to treat project teams as valued stakeholders. An organization can only attain true standardization when project management processes and practices are adhered to by all project managers [50].

5. Conclusions, limitations, and future studies

5.1 Conclusions

Software projects cannot run without software project teams; soft skills provided by team members are more critical in the software industry than 'hard' skills [90]. Yet the poor treatment of software project team members does not suggest that this empirical evidence has been heeded with seriousness. The inability of SPMs to attend to the needs of project stakeholders, SPTs included, frequently contributes to project failure.

As a contribution in arresting the neglect of SPTs, the authors of this study developed a model to assist SPMs in paying attention to the needs of these key stakeholders. One of the critical aspects of the model is the inclusion of the PMO to foster and standardize the implementation of the model in an organization, and thereby ensuring consistent and uniform approach in addressing the needs of SPTs within an organization. The lack of enforcing and standardizing of project management practices meant for addressing the needs of stakeholders (SPTs in the context of this paper) by existing stakeholder management tools was highlighted as one of their major limitations in Subsection 2.2.1. The inclusion of the PMO in the model designed by the authors of this study was intended to address this limitation. The use of the PMO for this purpose is in accordance with the claim by PMI [26] and Dai and Wells [19] that the enforcement and standardization of good project management practices in organizations are best handled by a PMO. The risks of lack of enforcement and non-standardization of project management practices and processes have far-reaching implications, including non-compliance by internal stakeholders (e.g., SPMs) in following the practices, challenges in enforcing compliance, and the inability to hold non-complying parties accountable.

The purpose of the study was to establish how to operationalize the enforcement and standardization of the model's overall function using the PMO roles and functions as outlined in literature. Two research questions were posed in this study to guide the research process in achieving the objective: ***RQ** 1: How can the PMO be used to enforce the overall function of the model?* and ***RQ** 2: How can the PMO be used to standardize the overall function of the model?* The following discussion indicates how the two research questions were answered by this study.

Subsections 4.1.1, 4.1.2, 4.1.3 and 4.1.4 outlined in detail how different PMO functions could be applied in enforcing the overall function of the model. Hence, the arguments presented in these subsections answered the first research question of this study. Similarly, the arguments presented in Subsections 4.2.1, 4.2.2 and 4.2.3 indicated how relevant functions of the PMO could assist in standardizing the overall function of the model, thereby answering the second research question.

5.2 Limitations and future studies

The interpretivism research approach involves attributing subjective meaning to that which is being interpreted, while concurrently the interpreter (researcher) may infer meaning from a personal point of reference [91] because an interpretive researcher is not a '*detached and disinterested observer*' [71]. This research approach, therefore, poses a limitation to this study. However, the use of the literature to guide the researchers' interpretations of the functions of the PMO moderated any potential bias in the interpretation. The researchers propose future studies to validate the practicality of this study's claim of the use of the PMO to foster and standardize the model's overall function, more so because the impact of functions and roles of PMOs are not yet fully understood [76].

Acknowledgments

The authors would like to thank our university for its financial support enabling the achievement of the study's objectives.

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

Failure factors of AI projects: results from expert interviews

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International Journal of
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Dennis Schlegel, Kajetan Schuler, Jens Westenberger, "Failure factors of AI projects: results from expert interviews", *International Journal of Information Systems and Project Management*, vol. 11, no. 3, pp. 25-40, 2023.

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Abstract:
In the last few years, business firms have substantially invested into the artificial intelligence (AI) technology. However, according to several studies, a significant percentage of AI projects fail or do not deliver business value. Due to the specific characteristics of AI projects, the existing body of knowledge about success and failure of information systems (IS) projects in general may not be transferrable to the context of AI. Therefore, the objective of our research has been to identify factors that can lead to AI project failure. Based on interviews with AI experts, this article identifies and discusses 12 factors that can lead to project failure. The factors can be further classified into five categories: unrealistic expectations, use case related issues, organizational constraints, lack of key resources, and technological issues. This research contributes to knowledge by providing new empirical data and synthesizing the results with related findings from prior studies. Our results have important managerial implications for firms that aim to adopt AI by helping the organizations to anticipate and actively manage risks in order to increase the chances of project success.

Keywords:
AI; artificial intelligence; machine learning; ML; failure; success.

DOI: 10.12821/ijispm110302

Manuscript received: 28 March 2022
Manuscript accepted: 18 December 2022

1. Introduction

The concept and term of artificial intelligence (AI) dates back to the 1950s [1]. Since then, the technology has lived through cycles of hype (AI spring) and stagnation (AI winter). Even though AI has become increasingly relevant, no unified definition of the term has emerged. Generally speaking, researchers agree that AI belongs to the field of computer sciences and is about developing independent applications that can solve problems on their own [2]. AI technologies can be divided into the subcategories of strong and weak AI. Applications of weak AI, such as speech recognition or fraud detection, are already available today and are constantly being further developed. The main characteristic of such applications is that they are developed for a special task and are not able to execute other tasks [3]. Distinct from this is strong AI, which attempts to replicate the human brain in order to develop an AI that is not limited to specific tasks [2, 3]. As strong AI is not available today [4], our paper focuses on weak AI. Weak AI is technologically based on machine learning (ML), which includes among others neural networks, and deep learning technologies. The terms ML and AI are often used synonymously, especially in a business context.

In the last years, both the adoption of AI, and the expectations regarding the economic potential of AI have risen sharply. Already in 2017, research has shown an increasing investment in AI by leading tech firms [5]. More recent studies even found that all companies in their sample were at least “actively evaluating use cases for ML applications” [6]. However, according to recent research [7], only few such projects are successful in delivering actual business value. Other sources even report that more than 80% of AI-related projects fail [8].

Hence, it is crucial to understand the factors that lead to failure of AI projects in order to avoid the pitfalls and fully exploit the potential of the technology. A large body of literature exists about the success and failure of Information Systems (IS) projects in general [9–14] or specific application types such as ERP systems [15–17]. However, due to the specific characteristics of AI, such as its algorithmic complexity and the broad and holistic changes that accompany the introduction of AI systems in organizations, these factors need to be revisited and extended to fit the context of AI [18].

A few recent publications have dealt with failure of AI-related projects [7, 8, 19–21]. Additionally, a number of studies have been conducted on related themes such as challenges [22], success factors [6] and organizational readiness for AI [23]. Although some of the previous studies provide interesting results, further research is clearly necessary due to the limited transferability of the findings to this paper’s aim, as well as, a number of other limitations in the existing body of literature (see section 2.2).

The aim of this study has therefore been to identify factors that lead to failure of AI projects in a general context. To reach this aim, were have conducted a literature review to synthesize prior findings in a systematic way. Additionally, we have collected new empirical data using qualitative, semi-structured interviews that were analyzed using an inductive coding approach [24–26].

This article makes a contribution to knowledge by providing new empirical data on critical factors leading to failure of AI projects, and synthesizing the findings with prior related studies to provide a more complete picture of the topic. The identified factors provide important insights and guidance for organizations to proactively increase the rate of success of their projects in order to exploit the potential of the AI technology and avoid costly project failure.

The paper is organized as follows. In section 2, a brief overview on the topic of success and failure of information systems (IS) is presented, before related work regarding AI projects is reviewed in detail. Subsequently, the research design is explained in section 3, followed by the presentation of the results in section 4. In section 5, we discuss the results and synthesize our findings with prior literature. Finally, we conclude by summarizing the main findings and our contribution to research, discussing practical implications for business firms, as well as, pointing out limitations of the study and opportunities for future research in this area.

2. Literature review

2.1 Success and failure of IS and AI projects

Success and failure of IS projects in general is a thoroughly studied subject. Before discussing typical causes of IS success and failure, these terms need to be defined. In general, success can be defined as “achieving the goals that have been established for an undertaking” [27]. On the flipside, IS failure can be defined as the perceived inability of the project to meet the requirements or expectations of various stakeholders [28]. The mentioned requirements and expectations can be manifold in this context, for example there are not only functional but also financial or time requirements.

As the goals of IS were not always perfectly clear, the definition of IS success was a challenge. In an attempt to identify dimensions of IS success, DeLone and McLean [29] undertook a literature review of papers published between 1981 and 1987. They identified six interdependent dimensions of IS success (system quality, information quality, use, user satisfaction, individual impact, and organizational impact) and used these in a model to explain IS success [29]. In the following years, this model was expanded and modified numerous times [10, 27, 30, 31]. Furthermore, both the original and the revised models have been validated to be good predictors of IS success [32–34]. In another stream of research, several studies attempted to identify determinants that have an effect on one or more of the stated dimensions [27, 35]. In total, over 50 determinants were identified to correlate with dimensions of IS success.

On the other hand, the failure of IS projects was also widely studied focusing on the discrepancy between actual and expected requirements. Similar to IS success, studies tried to investigate dimensions and determinants of IS failure [36, 37]. For example, Nelson [38] analyzed over 90 IS projects and concluded that there are 36 common mistakes in four categories: process, people, product and technology.

It can be concluded that IS success and failure is an intensely studied subject and existing models have been proven to be good predictors of IS success. However, due to the specific nature of AI projects, it is still largely unclear whether these results can be transferred to the context of AI projects. Due to specific characteristics of the AI technology, it can be assumed that AI has to be regarded separately from other digital technologies, as previously stated in the literature [23]. In the following paragraphs, we will first explain how characteristics of AI differ from other technologies, before addressing particularities of AI projects.

Looking at AI and the underlying technologies it can be seen that technology itself as well as technical characteristics [1, 39] differ from traditional IS/IT projects. As AI is not explicitly programmed to perform a specific task, but it rather learns from previous experience (data), the development and adoption of AI can be seen as a paradigm shift [2]. The shift and therefore the implementation and use of AI requires vastly different skills and is of higher complexity compared to typical software engineering projects. One example is, that most AI algorithms require deep statistical as well as mathematical knowledge. Furthermore, AI is a highly interdisciplinary field that requires not only software engineering and AI skills, but also domain knowledge for example [1].

Indeed, reports by practitioners indicate that AI projects differ from other projects in various characteristics. In his blog post, Mehta [40] presents several dimensions where AI projects differ from traditional IT or software development projects. For instance, the project focus of AI projects is on data exploration and insights instead of application development. Moreover, the goal of AI projects is often to use the technology strategically to transform the business, while traditional IS have more tactical goals. In terms of business knowledge, in traditional projects, business rules are given to programmers to be implemented in the software. In contrast, in AI projects the business data is used to discover the business rules from the data. Due to their more experimental trial and error approach, AI projects are also more difficult to manage to a fixed schedule than traditional projects.

Certainly, more research academic research is necessary to discover and confirm the differences between general IS and AI projects. However, the anecdotal evidence clearly indicates that AI projects do differ substantially from other projects in their goals and approaches. Considering these points, it can be assumed that not only AI projects but also the associated failure factors differ from traditional IS/IT projects and therefore need to be considered separately.

2.2 Related work and research gaps

In our literature review, we have identified several prior studies that have investigated research questions related to failure of AI projects, as well as, success factors, challenges, adoption and organizational readiness regarding AI [6, 8, 20–23, 41]. Table 1 summarizes important characteristics of the related work.

Table 1. Related literature.

Source	Object of analysis	Context	Theme/ construct	Method
Baier et al. [22]	Deployment and operation of ML	General	Challenges	Literature review and interviews
Bauer et al. [6]	ML	SME	Enablers and success factors	Interviews
Jöhnk et al. [23]	AI	General	Readiness	Literature review and interviews
Weiner [8]	AI/data science projects	General	Failure	Anecdotal evidence
Hou [20]	AI projects	Banking	Failure	Anecdotal evidence
Rychtyckyj and Turski [21]	Deployment of AI systems	General	Success and failure	Anecdotal evidence
Ermakova et al. [7]	Data-driven projects	General	Failure	Interviews and questionnaire survey
Reis et al. [19]	AI projects	Healthcare	Failure	Single case study

The comparison of the studies' characteristics shows that there are slightly different objects of analysis (e.g. AI, ML or data-driven projects). At the same time, different themes or constructs have been investigated (e.g. challenges, enablers, failure). Due to the limited number of studies that directly provide answers to our research aim, i.e. explicitly deal with failure of AI projects, we have extended the scope of our literature review to include the above-mentioned related themes. Although these previous results may lead to some interesting first assumptions regarding our research question, it has to be kept in mind that these constructs are different from failure factors. In our understanding, a challenge is defined more broadly as any "hurdle, barrier, concern, or critique" [42] whereas a failure factor leads to actual failure of a project, as defined in the previous section. At the same time, it has to be clearly distinguished between success and failure factors, as a failure factor does not necessarily have to be a success factor and vice-versa.

Besides these papers that deal specifically with AI or ML, we have searched for relevant previous research from less directly related fields, such as Big Data Analytics and Digital Strategy (not included in Table 1). The respective results from seminal articles [43–47] will be discussed in the discussion section of this paper (section 5) in order to compare the similarities and differences between the different fields and discuss possible implications.

Five literature sources were identified that discuss success or failure of AI projects or data-driven projects [7, 8, 19–21]. Two papers [20, 21] summarize "experiences with the development and deployment of AI systems" [21] in a specific company in a practice-oriented format. As these papers have the character of a practice report and lack scientific methodology, as well as, robust research design, they were excluded from a detailed discussion in this paper. In a similar vein, the book by Weiner [8] does provide interesting narratives about failure AI projects, but was excluded from our further analysis as it is not grounded on peer-reviewed research. Reis et al. [19] have conducted research into AI project failure based on a case study in the healthcare sector. The case study is based on a project in a large hospital to introduce a cognitive agent that was intended to assist physicians in their daily work and interact with patients. In this specific project, user resistance was identified as the reason for project failure. Consequently, the authors have conducted detailed analyses of the underlying causes of the non-acceptance and provide recommendations to overcome user resistance. Ermakova et al. [7] use a mixed methods approach to develop and administer an online survey with a sample of 112 experts. The focus of their research is "data-driven projects", i.e. data science in general, including AI and ML. In their approach, they do not distinguish between challenges and failure factors. Instead, the participants were asked to evaluate the perceived impact of challenges on the non-success of projects. Thus, the authors were able to make statements about the criticality of the challenges, i.e. their impact on failure.

Regarding the studies that do not directly regard failure, but related themes, Baier et al. [22] used interviews to analyze challenges particular to the deployment and operation of machine learning models. Another study focuses on general challenges in AI projects in the context of SMEs. To do so, Bauer et al. [6] correlate the identified success factors and challenges to the size and maturity of the companies. The data is collected using a survey approach with mainly CXOs or managing directors of SMEs. Jöhnk et al. [23] focus on AI readiness of companies. The authors collected data with semi-structured interviews focusing on factors that determine the readiness of companies in regard to AI.

Hence, we have selected the remaining fiver papers [6, 7, 19, 22, 23] for a detailed analysis as they were most relevant for the aim of this paper. For a better overview, the factors from these three studies are summarized in Table 2. The listed factors are abstracted to categories and may contain more than one individual factor presented in the studies, as well as, changes in wording due to the mapping to a uniform terminology. Additionally, the underlying theme or construct (challenges, failure factors etc.) was again mentioned in Table 2 to highlight the need for a careful interpretation when comparing the studies.

Table 2. Factors identified in previous studies.

Source	**Baier et al. [22]**	**Bauer et al. [6]**	**Ermakova et al. [7]**	**Jöhnk et al. [23]**	**Reis et al. [19]**
Theme/ construct	Challenges	Enablers and success factors	Challenges / failure factors	Readiness factors	Failure factors
Data	X	X	X	X	
Know how	X	X	X	X	
Infrastructure	X	X	X	X	
Project Management		X	X	X	
Communication	X		X	X	
Customer relation	X		X	X	
Acceptance	X		X		X
Ethics & Legal Issues	X		X	X	
Commitment		X		X	
Result validation	X	X			
Business Impact	X			X	
User friendliness	X				
Deployment	X				
Security			X		
Budget			X		

As shown in the table, some categories are mentioned by four out of five studies. One of the most prominent categories that was mentioned numerous times is *data*. As data is seen as the fuel for AI [41], it is not surprising that factors such as data quality, availability and governance are mentioned as important factors [6, 7, 22, 23]. In this category of our overview, we have summarized several factors that are dealt with in detail by the previous studies. For instance, Jöhnk et al. [23] list data flow as an interesting factor besides commonly mentioned factors like data availability, data accessibility and data quality. According to the authors, a good data flow enables AI professionals to “move data from its source to its use” by means of extract-transform-load processes, as well as, data pipelines and data streams. The work by Baier et al. [22] points toward important challenges in the area of data, such as imbalanced data or encrypted training data. Another factor that has been mentioned by most of the studies is *know how*. In the context of SME, Bauer et al. [6] see a lack of dedicated ML experts as an important size-related challenge experienced by this type of companies. At the same time, they state that an existing team in the area of business intelligence or data science can be an important success factor when it comes to the adoption of ML. This might be related to the fact that the use of ML models can be very challenging for employees that do not have a background in the field of data science. For this reason, other authors emphasize the need for user-friendly tools that enable non-technical employees to apply ML models [22]. Besides the obvious requirement of having a certain expertise in order to be able to work with AI-related technologies, an “AI awareness” also helps employees to have adequate expectations toward AI [23]. While many researchers focus on technical knowledge that is necessary for successful AI projects, one paper [22] also notices that domain knowledge can be crucial and can have an important implication on data quality. Ermakova et al. [7] see both, soft skills and hard skill, as important challenges for data-driven projects. Furthermore, different *infrastructure*-related factors seem to be a relevant challenges, for example regarding computational power. Depending on whether the necessary infrastructure is available in-house, time-consuming and complex investment decisions have to be made. However, due to cloud technologies, this problem can be mitigated [6, 22]. Factors that were mentioned by three of the studies are *communication, customer relation, acceptance*, as well as, *ethics and legal issues*.

While these prior studies provide seminal findings for their respective research aims, a number of research gaps remain with regard to the specific aim of our study. First, it has to be clearly stated that the results are not completely transferrable to our aim. As can be seen from Table 2, most of the prior studies have regarded different themes than failure. As previously stated, challenges, readiness factors or success factors can only be an approximation of failure factors. The study by Reis et al. [19] does deal with project failure. However, the research has been conducted in the specific context of healthcare and focuses on non-acceptance by users as one failure factor. The research by Ermakova et al. [7] does analyze failure in a more general context and is the most similar to this study. However, their object of analysis is data-driven projects as opposed to AI projects. It remains unclear, whether there is a significant difference in the definition that will have an impact on the results. Second, due to the limited number of studies and the mixed results, further research to corroborate the findings is necessary. The table shows that not all categories are mentioned in every study. The main reason for this might be the different focus of the studies. For example, Bauer et al. [6] focus on different company sizes while Jöhnk et al. [23] analyze readiness factors. Therefore, it can be concluded that collecting new empirical data for the specific question of AI project failure in a general context is clearly necessary. Finally, a comparison and synthesis of the related studies is required. The literature review in this section makes a first step toward an integrated discussion of the different papers.

3. Research design

For this study, a qualitative research design based on semi-structured expert interviews was chosen [24, 25]. Interviews are a common method in the IS discipline and have also been used as a method in prior related work (e.g. [6, 23]). The rationale behind choosing a qualitative methodology for this study is that the purpose of our study was to identify factors, as opposed to quantitatively testing them. In order to ensure the rigor of the qualitative research process, several measures were implemented [48]. These include critical discussion and reflection of methods and results throughout the different phases of the research process, as well as, redundant data analysis by different members of the team of authors, in order to minimize subjectivity and bias.

Following the recommendations for semi-structured interviews from the literature [49], we have developed an interview guide that consisted of a number of predetermined questions. However, the interviewer was also allowed to change the wording of questions, make clarifications and probe beyond the answers to the questions. As suggested by the methods literature, we have considered the objectives of our research, the type of data we were aiming to collect, as well as, conceptual areas from the literature review in the development of the instrument. Following common themes from the literature, we also included questions about challenges and success factors, besides our main concern, the question about project failure. Additionally, general introductory questions about project experiences and use cases were asked. The reason for this broad set of question was to stimulate an open discussion that will generate many aspects and ideas to be further discussed between the interviewer and respondents. However, for our framework of failure factors, as presented in the results section of this article, statements of the respondents were only considered if they explicitly referred to project failure. This was important in order to clearly distinguish between failure and challenges, as well as, between failure and success factors. All other statements were discarded for the purpose of this study in order to be precise in the measurement of the concept of failure.

To select the interview candidates, we have applied purposeful sampling in order to collect information-rich data that will help to illuminate the research questions [50]. In the selection of the candidates, our main focus was to include a diverse range of respondents in order to be able to identify as many relevant determinants of project failure as possible. Therefore, the sample includes AI experts that have heterogeneous professional backgrounds in terms of industry and company sizes, but also career levels and roles in their organization (see Table 3). In the sample, several candidates from consulting and software development firms are included that have worked in projects with different companies. Such experts are of less interest as an single case, but rather represent a more comprehensive source of knowledge based on cases in many firms. Hence, we were able to obtain sufficient data with a relatively low number of interviews. Following the concept of data saturation [51], we have not pre-determined a sample size. Instead, conducting new interviews was discontinued at a point when no new concepts had emerged from the data anymore. All of the interviews were conducted as audio or video calls between January and February 2021 by one of our authors, except one interview that was delivered in written form.

Table 3. Interview candidates.

#	Industry	Position	Focus/ expertise
1	Plant engineering	Team leader	Robotics and visual recognition
2	Software development	Founder and CEO	Visual recognition
3	Consulting	Senior consultant	AI in general
4	Software development	Developer	Natural Language Processing
5	Automotive	Development engineer	AI in sensor fusion
6	Automotive	Middle management	Driver assistance systems

With the consent of the participants, the interviews were recorded and subsequently transcribed using AI-based speech recognition. Subsequently, we used an inductive approach based on established methods for the analysis of qualitative data [25, 26] to derive a hierarchical coding structure. In a first step, the transcripts were inductively coded in an open coding approach. Finally, the codes were aggregated to several levels of higher-level categories based on their similarity in order to derive the factors presented in the results section of this paper. In order to avoid subjectivity, this analysis was first done independently by all authors and revised several times in an iterative process, before the consolidated version was finalized.

4. Results

4.1 Overview

Using the data from the interviews, a total of 12 factors that can lead to failure of AI projects were identified [18]. Based on our inductive method, these factors were further aggregated into the following five categories: Unrealistic expectations, use case related issues, organizational constraints, lack of key resources and technological issues (see Table 4).

Table 4. Categories and factors identified in the interviews.

Category	Factor
Unrealistic expectations	Misunderstanding of AI capabilities
	Thinking too big
Use case related issues	Missing value or cost-benefit ratio
	Complexity
	Low error tolerance

Category	Factor
Organizational constraints	Budget too low
	Regulations
Lack of key resources	Lack of employees with expertise
	Data availability
Technological issues	Model instability
	Lack of transparency (black box problem)
	Possible result manipulation

4.2 Unrealistic expectations

Factors regarding the expectations of AI projects are summarized in the category unrealistic expectations. Stakeholders and project members are often not fully aware of AI capabilities. This can lead to misunderstandings about technologies to be used. AI projects are sometimes only entitled as AI but are, in fact, not using any AI-related technologies. As interviewee 1 states, “most people have no idea what AI is actually supposed to be”, resulting in the situation that large, rule-based systems with human-made, pre-defined rules are programmed that are not based on AI technology. The expert even goes so far as to say that these systems “are not AI, but fake”. Such projects can clearly be considered as failure since they do not really lead to AI adoption.

Another factor related to unrealistic expectations is “thinking too big”. If expectations rise and managers become overly ambitious, projects scopes are getting wider and wider, until it is mostly impossible to make the projects work due to the lack of focus. A more successful approach to AI adoption, according to one expert, would be to “think in small steps” instead, in order to incrementally develop workable solutions. The root cause of too big expectations might often be linked to “too large promises” (Interviewee 3) that have been made.

4.3 Use case related issues

In general, use case related issues can also lead to project failure. The adoption of AI is sometimes done without value-adding use cases. In order to achieve a return on investment, value has to be generated, for instance by automating tasks that have previously been done by humans. If there are no additional revenues or cost savings, only expenses to introduce and operate the AI system, these projects fail in the sense of not delivering any economic benefits. One interviewee even stated, that “most use cases do not provide any value” (Interviewee 2).

Another failure factor is the use case complexity. If the complexity of a project surpasses the capabilities of the internal development teams, project can be “impossible to accomplish” (Interviewee 1). This means that project expectations and capabilities need to be aligned to prevent failure.

In special use cases, like autonomous driving, low error tolerance can lead to project failure. These use cases rely on precise and correct predictions and results, as error can have fatal outcomes. In AI projects, since the fidelity of results is only achieved after the models have been created, projects must be started first to verify accuracy. If the targeted and required accuracy is not achieved, projects are often discontinued.

4.4 Organizational constraints

Factors in the category organizational constraints represent external impacts on projects from within the company or the environment. Projects involving AI often represent a risk due to the uncertainty of the outcome. Therefore, often insufficient resources are allocated, leading to premature termination as they are running out of budget. However, the fact that often too low budgets are assigned is not only due to a reluctancy to invest, but also due to enormous budget requirements of AI projects. The budgets and resources are not only used to hire experts, but also to pay for training data and the training itself. Especially acquiring labelled datasets can be very expensive, as the generation of these datasets often requires a lot of human work in the first place. When these data are subsequently used to train AI models, also this next step is a huge effort, according to Interviewee 6. Interestingly, it was also mentioned that cost for hardware is not a relevant factor, as required machines or devices have become relatively inexpensive.

Additionally, regulations, internal or external, can cause issues for AI projects. One interviewee said, that there were “bureaucratic hurdles to even only attach a Raspberry Pi to an industrial machine” (Interviewee 2). However, the extent of this factor presumably depends on the country and company.

4.5 Key resources

Key resources, or the lack of those, were often described as a major influence on AI project failure. Three of the interviewees said that the lack of expertise was a key reason for the failure of AI projects. For example, Interviewee 6 mentioned that projects “sometimes fail because of the competencies of the employees, to be honest”. This problem can be related to other issues, like low budgets, as one interviewee mentioned: “If you put the wrong person, a person without enough knowledge, on an AI project, it is possible that the budget gets blown without any outcomes” (Interviewee 1).

As AI models strongly depend on the quantity and quality of training data, data availability is a factor that influences the project outcome. As an interviewee from the automotive sector mentioned, AI projects fail because correctly labelled training data is often not available or too expensive. This factors is “maybe even the most important one”, according to Interviewee 6’s opinion.

4.6 Technology

The technology itself is also a factor that can lead to project failure. Although Interviewee 2 mentioned that the technical implementation is usually not a reason for project failure in his context, several other interviewees did mention technology-related issues that can be critical.

One mentioned aspect is model instability. Companies rely on consistent results when it comes to AI algorithms. As the algorithms and systems are updated, there is “no guarantee that the systems work exactly like the last one and gives the same results” (Interviewee 4). This unpredictable behavior can lead to the termination of projects.

Furthermore, AI algorithms lack transparency as of how the algorithms ended up getting the result. This issue is especially relevant for results of neural networks and referred to as the so-called black box problem.

Furthermore, models can be manipulated to produce different results, e.g. if street signs are manipulated with stickers, there might be a wrong result interpreting it. The possible error introduced by manipulation can be too high to safely use the AI, depending on the context.

5. Discussion

Our results show that there are a variety of factors that can lead to failure of AI projects. A closer look at the factors reveals some interesting insights. First, it can be seen that technological issues can be one reason for failure. However, the statements of the candidates have shown that failure often seems to occur because of non-technical factors such as false expectations or lack of resources. Especially the lack of expertise or competent employees was emphasized by several interview candidates. Second, many factors or their detailed characteristics can hardly be anticipated before the start of an AI project and therefore cannot be appropriately considered in the planning of such a project. This can be observed, for example, in the factor *possible result manipulation*. At the beginning of a project, it is impossible to predict all possible ways how a result can be manipulated. Other factors, like the actual *complexity* of a use case or *model instability* can be equally difficult to estimate or anticipate. Therefore, it seems difficult to completely avoid possible project failure due to such reasons or to manage these risks as they often only emerge in the course of the project. On the other hand, some of the factors can be anticipated and managed in advance. For example, the needed know how for an AI project can be evaluated and actions can be taken. Furthermore, it can be checked if sufficient data is available to start an AI project.

An important contribution of our research is to distinguish failure factors from related constructs that have been discussed in prior work, such as challenges, readiness factors or success factors. By comparing our results (Table 4) with the prior results from related work (Table 2), we are able to draw the following conclusion: The factors *know how* [6, 7, 22, 23], *business impact* [22, 23] and *result validation* [6, 22] can be confirmed as being not only a challenge, but indeed critical for AI failure. Also *data* is a critical factor, when it comes to availability of suitable data. It can thus be seen that some of the already known challenges can also be concrete reasons for failure. On the other hand, some prominent factors from previous studies seem to be not as important for failure. These include the factors infrastructure, communication, deployment, user friendliness and customer relation. A possible explanation for the lower relevance with regard to failure is that these factors might indeed be relevant challenges in AI projects, but problems can be resolved if they occur and thus do not lead to project failure. For example, in the case of infrastructure, it is likely that problems related to this category can be resolved by investing in new on-site infrastructure or using cloud-based solutions.

Our research has additionally uncovered factors that have not been previously identified as failure factors or related constructs. These include *unrealistic expectations* and the specific *technological issues* of model instability and possible result manipulation. Overall, it can be summarized, that our study partially confirms prior results and also contributes new failure factors to the body of knowledge. Especially, regarding the prior study that is most similar to ours in terms of the research question [7], it seems that the results complement each other. However, due to the different methodology, measurement and classification of the factors, it is difficult to directly compare the results.

While we already have outlined previous related studies in the context of AI in section 2.2, it is also interesting to compare and synthesize our results with further findings from a broader context in order to discuss similarities and differences between different, related fields. Before the individual factors will be discussed in the subsequent paragraph, an overview of related context, as well as, seminal papers from the respective fields, is given. The first related context is the formulation of digital business strategies. For example, Holotiuk and Beimborn [43] have developed their Digital Business Strategy Framework based on a review of industry reports on digitalization. They have derived 40 critical success factors that are sorted into eight dimensions: sales and customer experience, culture and leadership, capabilities and HR competencies, foresight and vision, data and IT, operations and organization. Schuler and Schlegel [45] present a framework for corporate AI strategy formulation based on a systematic literature review that is supposed to outline important considerations when approaching AI adoption in a holistic approach. Based on inductive coding of factors extracted from the literature, they state that companies need to think about their capabilities, use cases, data, infrastructure and organization, as well as, ethical/legal constraints and managerial processes. The second stream of literature that can be considered as a related context is Big Data, being defined as data having high volume, velocity and variety, coming from different sources such as social media and video [47]. In his seminal paper, Watson [47] outlines success factors that organizations should consider in order to exploit the potential of big data analytics. According to the author, the factors include "a clear business need, strong committed sponsorship, alignment between the business and IT strategies, a fact-based decision-making culture, a strong data infrastructure, the right analytical tools, and people skilled in the use of analytics" [47]. In a similar vein, Saltz and Shamshurin [44] discuss key factors for a project's success in the context of Big Data team process methodologies. They find a large number of success factors that are categorized into the categories data, governance, process, objectives, team and tools. Finally, Phillips-Wren and Hoskisson [46] have conducted case study research in order to identify management challenges when it comes to formulating a big data strategy in the context of customer relationship management (CRM) in mid-sized hospitality industry firms. According to their results, the dimensions customer, CRM process, organizational alignment and CRM outputs need to be considered. They also identify common challenges such as inconsistent and unstandardized data, relevant data not known, leadership, finding people with relevant skills.

Comparing these results from a broader context and synthesizing them with our own research, it turns out that especially two factors that we have summarized as "key resources" in our research seem to be universally important, as they can be found in all of the studies in related fields: first, *employees with relevant skills*, and second, *data-related factors*.

(1) Employees with relevant skills: When it comes to digital business strategy, capabilities and competencies that will be required in the future, do not only encompass technological skills, but also the capability to redesign value chains and business models [43]. In the context of Big Data, Phillips-Wren and Hoskisson [46] explain the necessity to combine domain knowledge with analytical skills in order to provide business insights and improve decision-making. Not only on individual employee level, but also when it comes to team work, multidisciplinarity is stressed as a success factor in other studies [44]. Watson [47] states that different types of big data analytics users need have different roles which require different skillsets. On one end of the continuum, there are end users that need to have an understanding of the data's business impact without having to know the detailed functionality of algorithms. On the other hand, there are highly-trained data scientists who search for patterns in the data [47]. Despite the obvious importance of employees' skills and competencies, according to some authors, top managers in many firms have "not yet worked out strategies for recruiting and training the talent needed to get the most value from intelligent systems." [52]. It is therefore recommended that managers identify employees who are "both willing and able to collaborate with smart machines" [52]. An interesting question with regard to hiring and training is whether existing internal employees that become obsolete due to digital transformation can be reskilled and trained into highly-required digital profiles, or whether these skills need to be hired externally. Based on an analysis of job profiles in the context of robotic process automation (RPA), one study highly doubts the reskilling hypothesis due to the specific nature of the technical skills that are required in this technology [53], which certainly can also be transferred to the field of AI. Other authors [23] see upskilling as an important organizational necessity in order to enable staff to develop new AI-related skills.

(2) Data-related factors: In the context of Big Data, the literature highlights the importance of a strong data infrastructure: "When a strong data infrastructure is in place, applications can often be developed in days. Without a strong data infrastructure, applications may never be completed." [47]. In his article, Watson [47] discusses different relevant technological developments that have taken place in recent years, including CPU improvements, in-database analytics and columnar databases. Other authors focus less on the technical infrastructure and more on the data itself. Based on their case study in the hospitality sector, Phillips-Wren and Hoskisson [46] report day-to-day challenges when dealing with data, for example that users are not aware of the original source of data that is delivered by the IT department which leads to trust issues as these data are often also inconsistent. Several authors [43, 47] suggest using data and information from one central source in order to rely on one "single version (or source) of the truth for decision support data" [47]. Finally, further success factors related to data that have been identified in prior research are data quality management and ownership, as well as, data integration and security [44].

This discussion shows that there are indeed both, similarities, and differences between our results and the related prior research, as well as, the AI field and related contexts such as Big Data. The main similarity is certainly the importance of the general themes of people and know how, as well as, data-related factors. However, when it comes to the data-related factors, it has to be acknowledged that this is a very broad theme and the factors indeed do differ substantially when having a closer look. As previously noted, general aspects of data infrastructure and data management were emphasized in the literature in both the AI and Big Data field. However, our research has shown that these aspects are not critical to failure. Instead, the mere availability of labelled training data for the AI models is a key constraint. In a similar vein, some of the categories we have identified in our research are highly specific to AI. These include for example the problem of unrealistic expectations based on misunderstanding of AI capabilities and thinking too big. But also use case related issues such as the high complexity in AI projects, as well as, domain-specific technological issues including model instability and the black box problem, are specific to AI. On the other hand, it might be possible to transfer some findings from related fields to our context in order to give more specific guidance for the proactive management of failure factors. For example, regarding the management of skills and competencies in the firm by hiring and training employees, the existing body of literature from related contexts can be consulted to get further advise.

6. Conclusions

6.1 Summary and contribution to knowledge

The evidence from this study suggests that there are several factors that can lead to success or failure of AI projects. On the one hand, these factors include technological issues such as model instability or the black box problem. On the other hand, especially non-technological factors seem to play an important role, including misunderstanding of AI capabilities, or missing economic value of projects. Moreover, the lack of two types of key resources, employees with relevant expertise and adequate data, often lead to project failure. A comparison with prior studies from the context of AI and related field shows that these two key resources seem to common challenges in AI projects, as well as, Big Data and digital strategy contexts.

Our research makes a number of important contributions to the field. First of all, our research has underlined the importance of distinguishing between general challenges and failure factors of AI projects. Based on new empirical data, our study contributes to knowledge by making this distinction for previously known factors. For example, having adequate infrastructure to develop and employ AI applications, which has previously been identified as a challenge, is not a critical factor for project failure. Second, our new empirical data contributes to knowledge by identifying new factors such as unrealistic expectations. Finally, our article has synthesized and compared prior results from related work, as well as, embedded the results into the wider context of digital strategy and Big Data.

6.2 Implications

The findings of our research have important managerial implications for organizations that are planning to adopt AI. While some of the failure factors are hard to anticipate and manage, the relevance of other typical factors for a particular organization can easily be clarified in advance. Managers are advised to have clear and honest look at their organizations' capabilities and resources, as well as, their own expectations and understanding of AI, before starting an AI project. It is also recommended to conduct a systematic feasibility analysis before starting specific AI projects. After an evaluation of potential critical risks, appropriate measures can be taken to mitigate these risks.

If the risk of failure is estimated as too high, an honest acknowledgement of the organization's lack of AI readiness, combined with a mid-term roadmap to improve the capabilities, might be a better advise than rushing into disaster with one's eyes open. In order to improve their organizations' readiness for AI, especially the two key resources employees and data should be developed in the medium term by investing in upskilling and recruiting of high-profile employees, as well as, data infrastructure and management.

6.3 Limitations and further research

Our work may have some limitations. Given the qualitative approach and small sample size of our study, caution must be used in generalizing the findings or transferring them to other contexts. Additionally, due to the dynamic nature of the topic, we regard the results as a snapshot of current failure factors that has been taken in a certain moment and may evolve over time. Therefore, the results might have to be updated on an ongoing basis. However, the discussion of this study's results has shown that the results are overall plausible when comparing them to related studies which underlines the trustworthiness and credibility of our research.

Despite the limitations, we believe that our work lays the ground for further research in this area. We propose that further quantitative studies should be conducted to corroborate our findings and generate representative results based on the categories and factors identified in this study. For example, survey research design can be used to generate quantitative results on project failure, taking our identified factors, supplemented by other similar studies [7] as a basis for the design of the survey instrument. Additionally, future projects could deal with the question, how project failure can be avoided by systematically evaluating the risk factors found in this study.

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

CLIPS: Enriching interorganizational R&D project management by a project culture focus

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

Katharina Dieterich, Peter Ohlhausen, "CLIPS: Enriching interorganizational R&D project management by a project culture focus", *International Journal of Information Systems and Project Management*, vol. 11, no. 3, pp. 43-57, 2023.

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Available online at ijispm.sciencesphere.org

CLIPS: Enriching interorganizational R&D project management by a project culture focus

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Abstract:
Project managers still face management problems in interorganizational Research and Development (R&D) projects due to their limited authority. Addressing a project culture which is conducive to cooperation and innovation in interorganizational R&D project management demands commitment of individual project members and thus balances this limited authority. However, the relational collaboration level at which project culture manifests itself is not addressed by current project management approaches, or it is addressed only at a late stage. Consequently, project culture develops within a predefined framework of project organization and organized contents and thus is not actively targeted. Therefore, a focus shift towards project culture becomes necessary. This can be done by a project-culture-aware management. The method CLIPS actively supports interorganizational project members in this kind of management. It should be integrable in the common project management approaches, that with its application all collaboration levels are addressed in interorganizational R&D project management. The goal of this paper is to demonstrate the integrability of the method CLIPS and show how it can be integrated in common project management approaches. This enriches interorganizational R&D project management by a project culture focus.

Keywords:
interorganizational R&D projects; project culture; project-culture-aware management.

DOI: 10.12821/ijispm110303

Manuscript received: 31 March 2022
Manuscript accepted: 6 March 2023

1. Introduction

An increasing technology and product complexity leads to organizations networking with different partners for their Research and Development (R&D) activities [1, 2]. For solving complex problems, firms form nonequity partnerships with complementary partners [3]. When these partnerships have a temporary character and are formed to jointly accomplish a unique task in R&D, the result are interorganizational R&D projects [4–6]. Sydow and Braun [7] point out, that the interorganizational dimension for projects is still under-researched. There is a missing theoretical dimension for interorganizational projects, especially in terms of governance, routines and behavior [7]. According to vom Brocke and Lippe [4], there are two well-researched research streams for interorganizational R&D projects. While the first stream focuses on the understanding of management tasks and underlying processes, the second stream deals with extending and adapting existing project management knowledge. Here, focus is on a support provided by guidelines, techniques, and tools [4]. So far, culture is very little considered in the context of interorganizational R&D projects. The studies that consider culture focus on cultural differences, especially regarding university-industry collaborations [8, 9]. The focus lies here on a gap between organizational cultures. This gap results, for example, from differences in timescales or priorities and problems related to intellectual property rights and confidentially [8]. Furthermore, interorganizational R&D projects are mainly managed by using common project management standards, such as PMBOK [10], ICB [11] or PRINCE2 [12] and different agile approaches [13]. These approaches can all be applied to manage interorganizational R&D projects either as a single approach or in combination [13]. The use of these standards is beneficial, as their standardized characters promote a common understanding of project management [14]. However, these approaches do not focus on particularities of interorganizational R&D projects.

Interorganizational project team members belong to their permanent institution during the entire time of the temporary organization [15]. Thus, project managers only have a limited authority [4]. Furthermore, interorganizational project team members represent interests of their “home” institutions and are shaped by their cultures. Therefore, there is a high partner heterogeneity in cultures and interests [4]. Moreover, as non-equity partnerships are contractual agreements without equity investments, there are high transaction costs and opportunism risks in interorganizational R&D projects [3, 16]. These particularities often lead to different problems in practice such as protecting intellectual property, cultural differences, communication issues or a lack of trust [17]. As a result, a project culture evolves which is rather not conducive to innovation and cooperation. This hinders a successful project completion [18]. In this context, a project culture can be defined as the dynamic and complex system of shared artifacts, chosen beliefs and values and basic assumptions, which evolve as project rules over time [19, 20]. However, a project culture which is conducive to cooperation and innovation promotes team cohesion for jointly accomplishing a given task and thus is essential for interorganizational R&D projects [20]. In this way, commitment of individual project members is demanded and thus limited authority of interorganizational project managers can be balanced [18]. Therefore, this kind of project culture becomes essential in interorganizational R&D projects and thus should be addressed by interorganizational R&D project management.

In interorganizational R&D projects, networks form at both the firm and project levels. However, these are structured differently in terms of their nots and ties. At firm level, nots are the individual organizations and ties are the non-equity partnerships among these organizations [19]. At project-level, nots are the employees of the involved organizations and ties are their collaboration within the framework of the non-equity partnerships [19]. For interorganizational R&D project management the focus lies on the project level. Here, collaboration of interorganizational project members takes place on an operational level, more precisely on the three collaboration levels organization, relation and content [14, 19]. While the organizational level comprises for example project organization, structures and processes, the content-related level includes for example productive work, scope, time and cost [14]. The focus of the relational collaboration level lies on shaping relationships. On this level, a project culture manifests itself [14]. Project management operates on the strategic level above these three collaboration levels and needs to address them in order to ensure a productive collaboration and thus a successful project completion [19]. As already shown above, interorganizational R&D project management is mainly carried out using common agile-based approaches and/or project management standards [13] such as PMBOK [10], ICB [11] and PRINCE2 [12]. Dieterich [18] assigns the individual practices of these approaches to the three collaboration levels of Kuster et al. [14] described above. By this assignment, it becomes clear which levels are addressed or not addressed by the approaches. In addition, the inclusion of the individual process groups allows a phase-oriented view [18]. The analysis of Dieterich [18] reveals that the organizational and content-related level are strongly addressed by the project management practices. However, the relational collaboration level is addressed only little [18]. PMBOK addresses the relational level only in the execution project management process group by the practices “Manage project knowledge”, “Develop Team” and “Manage Team” [10, 18]. For ICB, the relational level is addressed in the monitoring and controlling project management process group by “Personal communication”, “Relationships and engagement”, “Teamwork” and “Conflict and crisis” [11, 18]. PRINCE2 focuses on the relational collaboration level even less. It can only be assumed, that in some activities the relational level is addressed [18]. For example, it can be assumed that the activity “capture previous lessons” in the “Starting up a project” phase [12] also includes lessons learned regarding relational issues [18]. Thus, if the relational level is addressed by these standards in project management process, it is addressed late in the process [18]. Agile-based approaches still take the relational level into account the most. This is because of the underlying twelve principles and four values of the agile manifesto, where individuals, their interactions and teamwork are actively targeted [18, 21]. Thus, in agile-based approaches, relationships, activities or roles are not guided by predefined rules, but by these four values and twelve principles [22]. However, these values and principles are rather tailored to software industry for whose support these have been defined. Thus, they are not specified for each individual project and context. They rather serve as a guideline for agile methods [22]. Hence, in an interorganizational project that is managed agilely, its individual project culture is not actively targeted either [18].

To sum up, these common project management standards and agile approaches do not address the relational level in their project management practices or address it only late [18]. Thus, interorganizational R&D projects are treated like intraorganizational projects in project management: To fulfil the given task project organization and content-related aspects are designed first. Then, in the second place, details on team collaboration are specified. This means, that the organizational and content-related level are addressed first and then the relational level [18]. By this approach, project culture evolves within a predefined framework of project organization and organized contents and thus is not actively targeted. Therefore, a focus shift towards project culture becomes necessary in interorganizational R&D project management [18]. This can be done by a project-culture-aware management [18–20]. In this management, project managers and team first determine collaboration details for accomplishing a given task. They set a common value basis and derive suitable norms [18, 19]. Then, based on these values and norms, they design content-related aspects and project organization [18–20]. By this approach, the targeted project culture sets the framework for the development of contents and project organization. This means, that the relational level is addressed first and then the content-related and organizational level. In the context of her dissertation project, Dieterich [18] developed the project-culture-aware management method CLIPS. CLIPS is an acronym that stands for “Cultural Links for Interorganizational Project Success” [18]. By applying this method, the focus in interorganizational R&D project management is placed on the relational collaboration level. In this way, interorganizational project members are actively supported in a project-culture-aware management of their project. One requirement of this method is to be integrable into the common project management approaches [18]. This is essential, because the organizational and content-related collaboration level are already fully addressed by these approaches. It seems that only the relational level is underestimated so far and consequently not actively addressed. Therefore, the method CLIPS should be integrable in these approaches, that with its application all collaboration levels are addressed in interorganizational R&D project management [18]. The goal of this paper is to demonstrate the integrability of the method CLIPS and show how it can be integrated in common project management approaches. This enriches interorganizational R&D project management by a project culture focus.

The structure of this paper is as follows. The following section provides a brief literature overview of different culture approaches and shows the research gap, that is filled by the project-culture-aware management method CLIPS. Then, in section three, the project-culture-aware method CLIPS is shortly presented. Section four shows how the method CLIPS can be included in common project management approaches. Section five shows a conclusion and avenues for further research.

2. Background

According to Sackmann [23], there are three different perspectives of culture: “culture as a variable”, “culture as a metaphor” and “culture as a dynamic construct”. In the “culture as a metaphor” perspective culture cannot be shaped but evolves from social interaction of organizational members. Thus, according to this perspective “an organization *is* a culture” ([23], p.21). According to the other two perspectives culture can be shaped. However, while underlying assumptions are deterministic/mechanistic in the “culture as a variable” perspective, they are probabilistic in the “culture as a dynamic construct” perspective [23]. Thus, even when representatives use same wordings such as “culture-aware management” there is a difference regarding a mechanistic or probabilistic execution [23].

In culture literature all different perspectives of culture are considered. However, for culture development the focus lies on the perspectives “culture as a variable” and “culture as a dynamic construct”. For these perspectives Dieterich [18] shows the following three-part area of tension:

- **Organizational vs. project culture:** Main cultural frameworks, process models and methods focus rather on organizational than project culture.
- **Frameworks vs. process models vs. methods:** Extant literature on (organizational) culture focuses on frameworks and process models.
- **Mechanistic/deterministic vs. probabilistic:** Most process models have rather a mechanistic/deterministic than probabilistic understanding [18, 23].

This area of tension can be clarified by the following. For organizational culture, there are frameworks which show which levels or dimensions a culture has [23–26], what types of cultures there are [27–29] and which factors are important to consider [30–32]. For project culture and project management culture respectively, there are only a few frameworks. Vaidyanathan [25] shows a framework with five key dimensions for project culture in organizations. This framework aims to support project initiation, planning or implementation in organizations to increase their strategic initiatives [25]. For project management culture, which is a broader construct than project culture, there are frameworks that include behaviors of stakeholders who are involved with the project in an organizational setting [26]. Furthermore, Seelhofer et al. [32] show a framework with relevant dimensions for a project management culture in the context of higher education. For a culture-aware management, Sackmann [33] describes concrete actions which address its structure in a conceptional way. These actions are based on cultural sensitivity and on an awareness process that could either be evolutionary or revolutionary. They refer to culture carriers, context, and leadership [33]. Dieterich et al. [19] show a two-part framework for a project-culture-aware management in interorganizational R&D projects. In the first part, they concentrate on project culture development. Here, they illustrate how project culture develops within different levels. In the second part, they show which factors are relevant to consider and designable to support a cooperative and innovative behavior in interorganizational R&D projects. In this context, they show a design chain of values, norms, operational and organizational structure [19].

Culture development as a demanding change process typically runs in the process phases analysis/diagnosis, design, implementation, and reflection [34]. In this context process models can be found above all. These models show “what to do”, i.e., which steps are to be carried out [35]. Thus, when it comes to change, develop or shape organizational culture, process models mainly show what managers and/or their change agents systematically have to do in the single steps of different-stage models [23, 36–38]. Moreover, these models give recommendations, such as to include the people who are addressed by cultural change [36]. Some process models also show how change affects organizational members [39, 40]. In this context, Sackmann [23] points out, that publications for culture change mostly show systematic approaches which rather have a deterministic understanding. However, humans, projects and teams are non-trivial systems that do not operate in a mechanistic manner [14, 23]. Here, managers should rather be enabled to create conditions that increase the probability of a desired behavior [23]. For a culture-aware management, Voigt [41, 42] shows a three-step process model with a deterministic/mechanistic understanding [18]. In the context of interorganizational R&D projects, Dieterich and Ohlhausen [20] show for a project-culture-aware management a closed-loop control for living values of a cooperative innovation culture. This closed-loop control describes the system “cooperative innovation culture” and illustrates relevant activities for designing and controlling project culture in interorganizational R&D-projects [20]. In contrast to process models, a method describes “how to do” something. Thus, it goes deeper than process models and describes in what way and with what results the steps need to be carried out [35]. So far, there are only a few methods that focus on the “how to do”-perspective in culture literature. These can be found in the diagnosis step of a cultural change process above all. For example, Cameron and Quinn [27] consider the “how to do” perspective for diagnosing organizational culture with the OCAI as a diagnosing instrument.

To sum up, project culture is very little considered in interorganizational R&D projects. Furthermore, there is an underrepresentation of the relational level in common project-management approaches and cultural frameworks, process models and methods do neither focus on project-level nor on a probabilistic understanding. Thus, there are extensive research needs on how to carry out a culture-aware management in a probabilistic way in interorganizational R&D projects. This research gap is closed by the project-culture-aware management method CLIPS [18] as it guides managers and project team through an entire culture development process and supports them in how to manage these projects project-culturally-aware in a probabilistic way.

3. CLIPS - A project-culture-aware management method

The overview of how to carry out a project-culture-aware management with the method CLIPS is divided into two parts. In the first part, the project-culture-aware process model of the method CLIPS is presented. It shows what steps interorganizational project members need to carry out for a project-culture-aware management [18]. In the second part, these steps, as the individual components of the method CLIPS, are described in more detail. Hence, focus is in this part on how these steps need to be carried out by interorganizational project members [18]. The method CLIPS is presented in this paper only as a summary, for details see [18].

3.1 What to do - Project-culture-aware process model

The project-culture-aware process model of the method CLIPS is a further development based on the models illustrated in Dieterich et al. [19] and Dieterich and Ohlhausen [20]. It comprises seven components (see Fig. 1) of which six can actively be designed. One component is a passive one that is influenced by the actively designable components. This highlights a probabilistic understanding of the method [18]. As there is a high heterogeneity in interests, project sponsors should identify in the first step a transparent project scope that represents a win-win situation for all involved organizations. Then, in the next step, all interorganizational project members jointly define values following a consensus principle. These values should be conducive to achieve this transparent project scope in cost and time. Based on these values, in the third step, project manager(s) and team derive norms following a consent principle [18]. Norms show specific rules of conduct in an interorganizational R&D project. In the fourth step, based on these derived norms, project manager(s) and team define the operational structure followed by the organizational structure of a project. Based on values, norms, operational and organizational structure a behavior of interorganizational project members results. This is the passive component of the process model. In the fifth step, the active component observation follows in which the resulting group behavior of interorganizational project members is observed. Then, in the sixth step, observations are jointly reflected by observers, project manager(s) and team [18]. Reflections take place after two different periods. A “small” reflection takes place every four weeks, since this is the period, in which consent decision need to be reviewed [43]. After this reflection follows a review and, if necessary, an adjustment of norms and/or organization to minimize discrepancies between actual and target condition of project culture. An “extended” reflection takes place every three months, since this is the approximate period within which humans form habits [44]. The consideration of habits is beneficial here because habits describe beliefs that are no longer aware to the respective persons due to their repeated use [23]. Hence, they are an automatic response to environment in thoughts and actions and thus belong to the basic assumptions of a culture [23, 44, 45]. After this “extended” reflection follows an actuality check, review and, if necessary, an adjustment of transparent scope, values, norms and/or organization. In this step, it is especially important to consider the reciprocal relationship between values and transparent project scope. As values need to be conducive to achieve transparent project scope in time and cost throughout the project, changes in project scope need to be checked regularly so that values can be adjusted accordingly [18]. The described project-culture-aware process model is illustrated in Fig. 1.

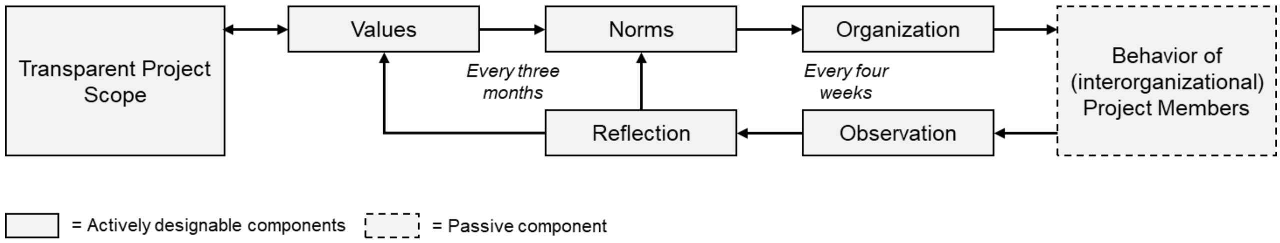

Fig 1. Project-culture-aware process model, following Dieterich [18]

3.2 How to do - Individual components

Transparent project scope: To pursue a collaborative strategy, interorganizational project outcome needs to be beneficial for all involved organizations (see Lewicki and Hiam [46]). Therefore, individual organizations should align their individual interests in a transparent process right from the beginning. Dieterich et al. [47] show a conceptual approach of a partner-finding process with a supporting tool, the Collaborative Iron Triangle. According to this approach, an initiating organization can start choosing either an effectuation or causation approach. Then, the initiating organization and their possible partner organizations document their individual scopes, the resources which they can/want to contribute and their desired time horizons for achieving their individual scopes. Afterwards, they search for suitable solutions. With an effectuation approach, organizations extend project scope and cost and level project time. With a causation approach, organizations separate project scope, extend project cost and level project time. These processes result in a win-win project outcome, complementary work effort, costs and resources and coherent time horizons [47]. The identification of a transparent project scope takes place on project governance level. On this level, sponsor-organizations and project sponsors are involved [48]. The use of the Collaborative Iron Triangle results in a collaboration agreement which considers the interests of all involved organizations. Furthermore, the tool ensures transparency for project scope. Thus, at the end of this component a commonly defined win-win project scope results, which includes the interests of the organizations involved. Furthermore, it is shown which organization is pursuing which interests and contributing which resources [18].

Values: As a defined values consensus forms the underlying form of culture [49, 50], values definition is the most essential step. Therefore, each interorganizational project member is involved. Hence, at the beginning, all interorganizational project members define values following a consensus principle [18]. The definition of values is done in three steps. In the first step, each project member should prioritize three to five values from a "values pool" by a pairwise comparison [51]. This number of values is beneficial, since humans can only remember a number of four in short-term memory [52]. The "values pool" shows 18 values of a project culture, that are conducive to cooperation and innovation, with their definitions [17, 18]. In this way, each project member has the same understanding of the values to be defined [18]. Then, in the second step, project members carry out a dialogue conference. For this conference, the rules of a democratic dialogue [53] are valid. Thus, at the beginning of the conference, these rules should be communicated to all interorganizational project members [18]. In accordance with these rules, interorganizational project members define valid values for collaboration in their interorganizational R&D project following a consensus principle. This can be done in heterogeneous and homogeneous teams in three rounds [54]. In the first round, they form heterogenous teams, i.e., teams with persons of different hierarchical levels. Here, each project member contributes his/her individual prioritized values to the discussion. Based on these values, each heterogeneous team defines three to five values following a consensus principle [18]. To prepare a consensus decision, project members can communicate their tendencies with a template, that shows five variants for voting [43]. Then, in the second round, they form homogeneous teams, i.e., teams with persons of the same hierarchical level. Based on the defined three to five values from round one, they define again three to five values following a consensus principle. These values form the basis for the final round three. In this round, all project members define three to five values based on the resulting values from round two following a consensus principle. This results in the final values. In the third step "manifestation of values", these final values are documented in a values-charter [18]. This values-charter needs to be agreed by each project member, for example, by signature. Furthermore, to link project culture with project success, values are documented in the "Collaborative Project Scorecard" [55]. This project control tool is beneficial because it takes both hard and soft factors of interorganizational projects into account. Hence, at the end of this component a values consensus results, which is agreed by all project members and forms the basis of their daily work. Furthermore, culture is considered in a strategic element for interorganizational project control [18].

Norms: Based on the values-charter, project manager, subproject managers and project team derive valid norms for collaboration following a consent principle. This derivation is done in two steps. In the first step, they derive norms according to the three rounds of a consent principle [56]. In the first round of a consent principle, project managers inform project team. Here, it is important to promote a common understanding of the term "norm" in the group. For this, a template with examples can be used. When a project team does not need more information for the derivation of norms, project manager asks project team for suggestions on derived norms. Within this process, project team can agree or disagree to what was previously said, add to it or come up with new ideas. Then, in the second round, project team can give their opinions on the resulting derived norms from the previous round. During these two rounds, no side talks are allowed and project manager documents new contributions [43, 56]. Based on the suggested norms, project manager is preparing a proposal for valid project norms in the third round and presents it to the team. If slight and/or heavy objections to the proposal arise, these are discussed and resolved. When there are no more objections, in the second step, the final derived norms are documented in a code of conduct. This code of conduct needs to be agreed from all members involved in the decision process, for example by signature. Thus, at the end of this component, derived norms result which guide project team and manager(s) in their daily work [18].

Organization: Based on the derived norms, project manager, subproject managers and project team design their operational and organizational structure. This design process comprises three steps. In the first step, based on the code of conduct, they shape operational structure [18]. Here, they can follow again the three rounds of a consent principle (see step "Norms" and Strauch and Reijmer [56]). Since the method CLIPS is supposed to be integrated in both classic and agile project management approaches, they should focus on "must-have" project management practices [57] to design the operational structure in interorganizational R&D projects. In this step, it also becomes important to design and implement a system for tracing intellectual property. Since an interorganizational R&D project is a temporary organization, according to Dieterich and Ohlhausen [58], this can be done with a private blockchain system. Since project members need to agree here, the origin of a contributed idea is acknowledged [58]. In this way, there is a transparence on who contributed when an idea that potentially can become intellectual property (IP). Thus, output separation is simplified, and IP issues are minimized. Hence, it is likely that more information than just the necessary ones are contributed [18]. In the second step, based on the operational structure, the organizational structure is shaped. Here, they can follow again the three rounds of a consent principle (see step "Norms" and Strauch and Reijmer [56]). Also in this step, focus lies on "must-have" project management practices [57]. For organizational structure, a "must-have" practice is a RACI-matrix. In this matrix, also the position "observers" should be included for the next four weeks [18]. One observer should observe around seven people [59] and each subproject must be represented. A project member can voluntarily enroll for the "observer" position in the RACI-matrix but must be observer at least once during an interorganizational project [18]. In the third step, defined elements of operational and organizational structure are documented in the target area of the reflection document. Hence, at the end of this component, an operational and organizational structure results which is based on the defined code of conduct and includes "must-have" project management practices for interorganizational R&D projects. Furthermore, observers are defined for the next four weeks [18].

Observation: The defined transparent scope, values, norms, and organization set the framework within project members work on accomplishing the given task. The observers defined in the previously step "organization" evaluate the collaborative behavior of project manager, subproject managers and project team. In addition, each project team member observes himself/herself during the entire project duration [18]. For observation, observers can follow the diagnosis-intervention-cycle [60]. Thus, they first observe the collaborative behavior of project team and managers. For this, they can use the PLA-CHECK approach (see, for example Doke and Risley [59]) as a guide. To observe the collaborative behavior, they make notes in an observation template of how many people present adhere in which situation to the code of conduct. This results in subjective perceived engagement rates. Furthermore, they document their perceived operational and organizational structure. By this process, each observer documents the actual state per week. In addition, each project member observes himself/herself during the entire project duration by tracking his/her behavior by means of the code of conduct. For this, they can use a self-observation template [18]. In the second step, each observer infers meaning of the observed collaborative behavior. After four weeks, observers meet once before the reflection meeting and combine their weekly observation templates. This can be done, for example, with a spreadsheet software to calculate combined subjective engagement rates. By this software, these rates also can be represented graphically. Thus, a development in collaborative behavior can be read [18]. In the third step, observers prepare an intervention. For this, they transfer the summarized notes and combined subjective engagement rates in the actual area of the reflection template. Then, they invite project members to the reflection meeting. Hence, at the end of this component an actual condition results which can be contrasted with the target one [18].

"Small" Reflection: Every four weeks project manager, subproject managers, project team and observers jointly reflect observed collaborative behavior. This is done in two processes. In the first step, each project member assesses the actual condition in terms of the degree of norms lived. For this, they use a ten-point scale which runs from "not lived" to "fully lived". The calculated average is then included to the actual area of the reflection template [18]. Afterwards, observers present the observed actual condition and its development over the last four weeks to the others. Then, they ask for other opinions (see diagnosis-intervention-cycle [60]). Here, project members can voluntarily complement the actual state with their self-observations. In the second step, when there are no more additions, they jointly analyze the resulting actual condition. Then, they identify discrepancies between actual and target condition and determine the reasons for them. Hence, at the end of this component, needs for action result or not [18].

Norms | Organization | Observation: Based on identified discrepancies, project manager, subproject managers and project team adapt norms and/or organization, if necessary. In any case, observers for the next four weeks are defined and documented in the RACI-matrix of the project. Afterwards, project members proceed with their daily work which is then observed again (see step "Observation") [18].

"Extended" Reflection: Every three months, reflection is extended. This means that, beside living of norms, also living of values is jointly reflected by project manager, subproject managers, project team and observers. The extended reflection is done in three steps. However, the first and second step are almost the same as in "small" reflection. There is only an adaptation in the first step. Here, beside the degree of norms lived, also the degree of values lived is assessed by project members using the ten-point scale described above. The calculated average for values is then also included to the actual area of the reflection template [18]. Then, step two is carried out as in "small" reflection. Afterwards, in step three, they prepare actual conditions and their developments of the last three months, also after adaptations. Hence, at the end of this component, in addition to needs for action, there is an overview of the actual conditions of the last three months [18].

Values | Project Scope: After three months, project manager reports developments of actual conditions and potential adaptations in norms and/or organization to all interorganizational project members. Then, all members check whether there are changes in interests of the individual organizations that could influence project scope. For this, they can use the Collaborative Iron Triangle [47]. If project scope has changed, interorganizational project members need to check whether the defined values are still up to date and conducive to achieve it in time and cost. Moreover, they should check whether other values became more important in the last three months [18]. Furthermore, if some values are already fully lived by project members, i.e., values became basic assumptions, interorganizational project members can start prioritizing further values. For this, they can carry out again a dialogue conference (see step "Values"). Hence, at the end of this component, a project scope results that is reviewed for possible changes in interests of the involved individual organizations. Furthermore, values are checked and, if necessary, values basis and the Collaborative Project Scorecard are updated [18].

4. Integration of the method CLIPS in common project management approaches

In order to demonstrate the integrability of the components of the method CLIPS [18] in common project management approaches and to show how they can be integrated there, the six actively designable components are analyzed in more detail. Here, for common project management approaches, focus is on PMBOK [10], PRINCE2 [12] and ICB [11] as well as on the underlying construct of agile project management approaches. For the analysis, the assignment of Dieterich [18] to identify the underrepresentation of the relational collaboration level, explained in section 1, can serve as a basis. This results in two analysis criteria. The first criterion is collaboration level [14]. In terms of this criterion, it is evaluated whether the individual components of the method CLIPS focus on organizational, relational, or content-related issues. Organizational issues involve for example project organization, structures or processes [14]. Relational issues deal with the relationships of interorganizational project team members and content-related issues focus on scope, time and cost as well as on productive work [14]. The second criterion is process group. In terms of this criterion, it is evaluated in which process group processes and actions of the individual components of the method CLIPS take place. Here, focus is on the process group frameworks of PMBOK [10] and PRINCE2 [12]. This is because the elements of the competence-based project management approach ICB can be assigned to the process groups of PMBOK (see for more information Dieterich [18]). The process group framework of PMBOK shows the five process groups “initiating process group”, “planning process group”, “executing process group”, “monitoring and controlling process group” and “closing process group” [10]. The process group framework of PRINCE2 shows the seven process groups “Starting Up a Project”, “Directing a Project”, “Initiating a Project”, “Controlling a Stage”, “Managing Product Delivery”, “Managing a Stage Boundary” and “Closing a Project” [12]. In terms of agile project management approaches, there are many different agile methods with different processes. However, agile methods have the two key elements “agile manifesto” [21] and “iteration cycles” as an underlying construct in common [22]. Therefore, focus is laid on these two key elements. Here, the inclusion of the components of the method CLIPS is shown in a conceptional way.

The analysis shows that the method CLIPS does not conflict with established project management approaches. Rather, it addresses the relational collaboration level where current project management approaches do not. Thus, the method CLIPS can be integrated in PMBOK [10], PRINCE2 [12] and ICB [11] as well as in agile project management approaches. In the following it is shown how the components of the method CLIPS can be included in the process group framework of PMBOK (for ICB [11] and PMBOK [10]) and of PRINCE2 [12]. Furthermore, it is described how they can be integrated in agile approaches.

As Table 1 shows, for PMBOK and ICB, single components of the method CLIPS can be included in the “initiating”, “planning”, “execution” and “monitoring and controlling” project management process groups. As the project starts, partner-finding can be carried out with the Collaborative Iron Triangle [47] to determine a win-win project scope, complementary resources, and a coherent time horizon. Furthermore, a collaboration agreement can be formed with it. For PMBOK, this agreement can be included in the project charter which is developed in the “initiating” process group [10]. For ICB, this agreement can be considered in the competences “project design” and “requirements and objectives” [11]. By this integration, the component “transparent project scope” addresses the organizational and content-related level and thus defines the task to be accomplished. This sets a framework within which interorganizational R&D project management operates for a successful project completion. Once the task is set, collaboration details need to be specified in order to ensure a focus shift in project management towards project culture [18]. Therefore, the component “values” is also included in the “initiating” process group. This component serves as a starting point for interorganizational R&D project management. In the “planning” process group, norms are derived from the defined values. In this way, the previously unaddressed relational collaboration level is addressed in this process group. Furthermore, in this process group, according to PMBOK [10] and ICB [11], operational and organizational structure is defined. This takes place on the organizational and content-related collaboration level. Thus, the focus shift becomes evident here, as the operational and organizational structure is now designed based on the defined code of conduct [18]. Furthermore, as focus is for the component “organization” on the “must-have” project management practices (see for “must-have” practices Fernandes et al. [57]), operational and organizational structure is adapted to interorganizational R&D projects. As working on the task is done in the “execution” process group [10], observational actions of the method CLIPS are carried out there. Thus, for PMBOK, beside manage and develop team and manage project knowledge [10], the relational level is addressed by the component observation. As reviews are carried out in the "monitoring and controlling" process group [10], the component "reflection" addresses the relational collaboration level there. For ICB, the component "reflection" complements the competences "Personal communication", "Relationships and engagement", "Teamwork", "Conflict and crisis" [11].

Table 1: Integration of actively designable components of the method CLIPS to PMBOK and ICB

Collaboration Levels*	PM Process Groups**				
	Initiating Process Group	**Planning Process Group**	**Executing Process Group**	**Monitoring and Controlling Process Group**	**Closing Process Group**
Organization	Organizational PM practices **Transparent Project-Scope**	Organizational PM practices **Organization**	Organizational PM practices	Organizational PM practices	Organizational PM practices
Relation	**Values**	**Norms**	PMBOK**: Relational PM practices **Observation**	ICB***: Relational PM practices **Reflection**	-
Content	**Transparent Project-Scope** Content-related PM practices	**Organization** Content-related PM practices	Content-related PM practices	Content-related PM practices	Content-related PM practices

Actively designable components of the method CLIPS; *see Kuster et al. [14]; **see PMI [10]; ***see IPMA [11]; PM = Project Management

For PRINCE2, as Table 2 shows, components of the method CLIPS can be integrated in the processes "Starting up a Project", "Initiating a project" and "Controlling a stage". In the process "Starting up a project", an outline of a Business Case is prepared, and a project brief is assembled [12]. Thus, the component "transparent project scope" can be integrated here. In this way, the Business Case outline and project brief is adapted to interorganizational R&D projects, and the content-related and organizational collaboration level are addressed to define the task to be accomplished. In the process "Initiating a project", the operational and organizational structure is defined [12]. Thus, in order to ensure a focus shift, values and norms need to be defined in this step. In this way, organization can be designed based on a code of conduct. Hence, the relational collaboration level is addressed firstly by values and norms. Afterwards, the content-related and organizational level is addressed by the component "organization". By focusing on the "must-have" project management practices [57] here, operational and organizational structure is adapted to interorganizational R&D projects. In the process "Controlling a stage", defined activities such as work packages, Business Case or risks are tracked [12]. So far, the focus of this process lies on the content-related and organizational collaboration level. By integrating the components "observation" and "reflection", also the relational level is addressed. Therefore, there is an add-on of observation activities and joint reflections in the monitoring process. So far, project managers are responsible for this stage [12]. However, by integration of observation and reflection activities, also observers and project team should be involved here.

For agile project management approaches, the integration of the method CLIPS is shown in a conceptual way focusing on the two key elements "agile manifesto" [21] and "iteration cycles" [22]. Here, for the definition of a transparent project scope an effectuation approach should be chosen. This is beneficial to agile approaches, as means are set and scope is flexible [14, 47]. Then, the Collaborative Iron Triangle can be used to form a collaboration agreement [47]. Afterwards, values need to be defined. From the defined values norms are derived. Then, the resulting code of conduct serves as the basis for designing operational and organizational project structure. Since many agile project management methods include iterations, the components "observation" and "reflection" should be integrated to them. However, since iteration lengths are mainly shorter than four weeks/three months (see for an overview Flora and Chande [22]), reflection period should be aligned with agile iteration cycles. Thus, by integrating the method CLIPS in agile project management approaches, the four values and twelve principles from the agile manifesto are complemented by project individual values and norms. Furthermore, agile approaches are adapted to interorganizational R&D projects.

Table 2: Integration of actively designable components of the method CLIPS to PRINCE2

Collaboration Levels*		PRINCE2 Processes**						
		Starting Up a Project	**Directing a Project**	**Initiating a Project**	**Controlling a Stage**	**Managing Product Delivery**	**Managing a Stage Boundary**	**Closing a Project**
	Organization	Organizational PM practices **Transparent Project-Scope**	Organizational PM practices	Organizational PM practices **Organization**	Organizational PM practices	Organizational PM practices	Organizational PM practices	Organizational PM practices
	Relation	-	-	**Values** **Norms**	**Observation** **Reflection**	-	-	-
	Content	**Transparent Project-Scope** Content-related PM practices	Content-related PM practices	**Organization** Content-related PM practices	Content-related PM practices	Content-related PM practices	Content-related PM practices	Content-related PM practices

Actively designable components of the method CLIPS; *see Kuster et al. [14]; **see OGC [12]; PM = Project Management

5. Conclusion and future research in the context of interorganizational R&D projects

Since there are still problems in managing interorganizational R&D projects, a promising management approach is to address project culture there. However, in interorganizational R&D project management, the relational collaboration level at which project culture manifests itself [14] is still underrepresented. Common project management standards and agile approaches do not address this level in their project management practices or address it only late [18]. Thus, project culture evolves within a predefined framework of project organization and organized contents and is not actively targeted. Therefore, a focus shift towards project culture becomes necessary in interorganizational R&D project management [18]. This can be done by a project-culture-aware management [18–20]. The method CLIPS actively supports interorganizational project members in this kind of management. It should be integrable in the common project management approaches, that with its application all collaboration levels are addressed in interorganizational R&D project management [18]. Thus, the goal of this paper is to demonstrate the integrability of the method CLIPS and show how it can be integrated in common project management approaches.

The method CLIPS empowers project sponsors, managers, and team to manage interorganizational R&D projects project-culturally-aware on a probabilistic basis. It guides them through a closed-loop control of seven components. While six components are actively designable, one is a passive component highlighting the probabilistic understanding of the method CLIPS [18]. The analysis shows that the actively designable components can be integrated into common project management approaches. For ICB [11] and PMBOK [10], they can be integrated into initiating, planning, executing, monitoring and controlling process groups. For PRINCE2 [12], these components can be integrated in the three processes "Starting up a project", "Initiating a project" and "Controlling a stage". By this integration, interorganizational R&D project management is enriched by a project culture focus. First evaluations with organizations from different industries and of different sizes show that there is interest from practice in the method CLIPS. However, processes of the method CLIPS should be further simplified [18]. In addition, further empirical studies should be carried out focusing on an integration of the method CLIPS in classic and agile project management approaches. In general, a project-culture-aware management is a promising research direction where researchers should further elaborate on. As the importance of project work increases – in Germany, Norway and Iceland project work is about nearly one third of all economic activities [61] – a project-culture-aware management could also be beneficial in large firms with different organizational units. Since the analyzed project management approaches are generally valid for project management, the method CLIPS is also applicable for intraorganizational projects. Here, the interorganizational focus of the method

CLIPS is an advantage as this method was developed for project members whose trust basis is little and interests in individual output maximation is high. However, if project context is different from R&D, the “values pool” should be adapted accordingly.

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Peter Ohlhausen has been working at Fraunhofer IAO since 1993. There he is head of the Research Coordination department. At the Reutlingen University ESB he is responsible for technology and innovation management. The key fields of his research are innovation management, R&D management, knowledge management, diversity in innovation management. He led numerous projects dealing with project management implementation, knowledge management and the reorganisation of R&D departments in industry like Bosch, EADS, BAe, Casa, Siemens Medical, Daimler and several SMEs. Furthermore, he worked on several projects dealing with diversity in innovation management and in research institutions. He had a great interest in the topic of science fiction as an impetus for innovation.

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

Critical success factors for DevOps adoption in information systems development

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

J. A. V. M. K. Jayakody, W. M. J. I. Wijayanayake, "Critical success factors for DevOps adoption in information systems development", *International Journal of Information Systems and Project Management*, vol. 11, no. 3, pp. 60-82, 2023.

International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

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Abstract:
Adopting DevOps is challenging since it makes a significant paradigm shift in the Information Systems Development process. DevOps is a trending approach attached to the Agile Software Development Methodology, which facilitates adaptation to the customers' rapidly-changing requirements. It keeps one front step by introducing software operators who support the transmission between software and implementation into the software development team by confirming faster development, quality assurance, and easy maintenance of Information Systems (IS). However, software development companies reported challenges in adopting DevOps. It is critical to control those challenges while getting hold of the benefits by studying Critical Success Factors (CSF) for adopting DevOps. This study aimed to analyze the use of DevOps approach in IS developments by exploring CSFs of DevOps. A systematic literature review was applied to identify CSFs. These factors were confirmed by interviewing DevOps practitioners while identifying more frequent CSFs in the software development industry. Finally, the research presents a conceptual model for CSFs of DevOps, which is a guide to reap the DevOps benefits while reducing the hurdles for enhancing the success of IS. The conceptual model presents CSFs of DevOps by grouping them into four areas: collaborative culture, DevOps practices, proficient DevOps team, and metrics & measurement.

Keywords:
DevOps; critical success factors; information systems; agile software development methodology.

DOI: 10.12821/ijispm110304

Manuscript received: 9 September 2022
Manuscript accepted: 18 April 2023

1. Introduction

DevOps is a trending approach for increasing the success of Information Systems (IS) development projects. It creates a collaborative culture by combining IS development and operations teams. IS development team is responsible for reacting to market changes and delivering new software assets as soon as possible. The IS operations team is responsible for providing stable, truthful, and secure service to the client [1]. IS distribute information, knowledge, and digital products by collecting, processing, and storing information. Developing high-quality and reliable custom information systems is a challenging project that typically goes through the life cycle called Software Development Life Cycle (SDLC). SDLC involves several stages as; planning, analyzing, designing, building, testing, deploying, and maintenance. The software development methodology is a framework to plan and control this process, and various software development methodologies have been applied over the past decades.

Today, the Agile software development methodology has become more popular in the software development industry since it facilitates adoption with the customers' rapidly changing requirements [2]. The agile Development team comprises both software developers and customer representatives, and they should be well-informed and competent to make the possible adjustments in the development process [3]. Sense of agility in software development is the ability to adapt and react quickly, effectively, and appropriately to environmental changes [4]. Since these Agile methods use fewer instructions when analyzing, designing, and implementing the software requirements, they are easy to use than the traditional heavy-weight methods. Moreover, agile distributes projects into several small projects called sprints. It enables software development teams to provide consumers with certified goods as soon as possible [4].

However, Agile methodology mainly focuses on the customer requirements and maintaining good rapport with the customers rather than on the non-functional requirements of the software, such as maintainability, required resources, portability, and performance. This might cause the process of developing software to fail [4]. Sometimes Agile methodology is unsuccessful when software is developed for customers from diverse backgrounds [4]. Additionally, there are software operating teams' challenges when attempting to deploy software in a real-world setting, emphasizing how crucial communication with the operating team is essential during the development process [5]. The separation of software development and software operations leads to delays in discovering errors and shifts the deadline of projects [6]. Shortcomings of the Agile methodology forced software development teams to include software operating teams in their team. DevOps keeps one front step by introducing software operators who can support the transmission between software and implementation into the software development team [7]. However, only some scientific surveys are available on DevOps [8],[9].

Most researchers have introduced DevOps as a new approach to the Agile software development methodology, while few have discussed it as a new software development methodology [6],[10]. However, according to the common opinion, it is challenging to consider DevOps as a new software development methodology since it uses the same principles as Agile methodology and does not have a standard definition and characteristics. Furthermore, given that DevOps refers to complete automation in the development and delivery of software [11], some scholars have described DevOps adoption as a new paradigm in the software development process [12]. However, this DevOps approach has attracted the attention of software development companies in recent years since it delivers more advantages to them. DevOps confirms the faster development, quality assurance, and easy maintenance of the information systems, dropping the challenges created by the Agile software development methodology [11],[13],[14]. Moreover, it enables software development companies to take faster feedback from customers, reduce deployment costs, and mainly reduce the risk of software failures [15], [16],[17].

Nevertheless, while practicing this approach, the software development team faces some challenges, and recent empirical studies demonstrate the challenges of adopting DevOps. Since the DevOps approach is a novel concept in the software development industry, it is challenging to find DevOps experts [18] and difficult to use DevOps tools and technologies [19]. Furthermore, it is challenging to maintain the software quality while speeding up the development process with DevOps. Similarly, previous research observed that the most critical challenge is the cultural changes [20] leading to effective communication problems. According to a Gartner survey [21] conducted in 2019, the biggest challenge for an organization's expansion of the use of DevOps is recorded as the people issue. Software development projects can fail again because of the challenges of the DevOps approach. But these industry experiences are not frequently surveyed or reported by researchers [22],[23],[24]. However, it is critical to control the challenges while getting hold of the benefits of DevOps for proper adoption of DevOps. It is required to comply with the critical success factors of DevOps for attaining a victorious DevOps adoption. The critical success factors realize the IS development process's continuous, verified, significant, and measurable success [25]. Even so, software development professionals need to know more about the DevOps success elements [18],[26]. Furthermore, existing evidence indicates that the critical success factors surrounding the adoption of DevOps need to be adequately defined while Information Systems are in the row to success. It is, therefore, essential to study the DevOps critical success factors which help to face the DevOps challenges.

Our study aimed to analyze the use of the DevOps approach in software development by exploring the critical success factors of DevOps. Two research questions were defined:

RQ 1: What are the critical success factors of DevOps reported by other researchers in Information Systems Development?

RQ 2: What factors are considered by experts as the DevOps critical success factors, and do they confirm the success factors listed in the literature?

A systematic literature review (SLR) method was applied to identify the critical success factors of DevOps. The identified success factors compared with the practical software development environment by conducting interviews with DevOps practitioners. Finally, the research presents a conceptual model for the critical success factors of the DevOps approach, which guides the adoption of DevOps and earning benefits. The conceptual model presents critical success factors of DevOps by grouping them into four areas: collaborative culture, DevOps practices, proficient DevOps team, and metrics and measurement. The paper consists of six sections. The first section includes an introduction to the study, while the second section discusses the background and related works. Section three introduces the methodology carried out for the research. Section four presents the findings obtained, while section five discusses the results. Finally, the paper concludes with the last section by summarizing the main findings of the research and presenting several directions for further study in this domain.

2. Background and related works

2.1 DevOps in information systems development

Today, the software development industry trend is DevOps, which is considered the next step of the Agile methodology. It resolves the conflicts between developers and operations staff during the deployment by strengthening communication, integration, and collaboration. According to Mishr and Otaiwi [22], the primary goal of DevOps is to increase development speed, frequency, and quality. DevOps has been defined in many ways by different researchers. Lwakatare [27] discusses the DevOps as “a mindset change substantiated with a set of practices to encourage cross-functional collaboration between teams; especially development and Information Technology (IT) operations; within a software development organization, in order to operate resilient systems and accelerate the delivery of changes”. According to Perera et al. [28] a popular definition is “DevOps is a mix of patterns intended to improve collaboration between software development and operations”. Recently, DevOps has emphasized as “a cultural shift which encourages great collaboration to foster building better quality software more quickly and more reliably” [29]. Senapathi et al. [30] presented DevOps transitional journey as “the period of time where software developers transition from just handing over their completed work to system administrators, to actually taking ownership and responsibility themselves”. By the words of a program manager at Microsoft, “DevOps is the union of people, process and product to enable continuous delivery of value to their end users” [31]. Lately, DevOps is defined by Khan et al. [32] as “set of practices and cultural movements to brake the barrios between development and operation teams to improve communication and collaboration”. There is no standard definition for DevOps.

According to the DevOps model presented by Gartner [21], the DevOps process consists of seven continuous steps for successful DevOps practice. It includes parallel and ongoing seven activities as plan, create, verify, prepare, release, configure, and monitor. Farroha and Farroha [33] have discussed the main objectives of DevOps as delivering measurable business value through continuous and high-quality service delivery, emphasizing agility in all areas, including technology, process, and human factors, breakdown barriers between development and operations by enabling trust and shared ownership, support innovation and encouraging collaboration, and manage dynamic compliance - access/sharing laws are changing. Similarly, several researchers mention many benefits offered by the DevOps approach. Mainly it reduces project completion time, improves software quality, and improves customer satisfaction. In the words of Senapathi et al. [30], DevOps improve customer experience through quicker innovations, an appetite for experimentation, and more frequent releases [16]. More than those advantages, Batra and Jatain explained that [34] DevOps reduces the software design's complexity, stabilizes the operation environment, and creates goodwill with satisfied customers. Moreover, according to Mohammad [35], DevOps enables software development teams to reduce operational costs, improve productivity, ensure high accessibility, and improve reliability while optimizing software performance. Based on the idea generated by Kalliosaari et al. [16], DevOps also benefit the DevOps team members by improving their well-being because frequent releases reduce their stress level. These research findings prove that DevOps has become a silver bullet to the software development industry since it provides various benefits to software developers, operating teams, and their customers.

2.2 Challenges of DevOps adoption

Adopting DevOps in Information System Development projects provides such benefits as same as it brings challenges [13],[22],[32]. Removing the gap between software developers and the operating team changes the organizational culture [22],[18]. According to Lwakatare [27], other than the company culture, DevOps affects the processes, products, associated technologies, and organizational structures used in software development and operations processes. More than that, lack of (DevOps) experienced and knowledgeable people, lack of management support for DevOps adoption, difficulties in changing habits and mindsets of the team members, increased cost of development, and challenges for making a highly secured development process have been specified as the challenges for DevOps adoption in IS projects by Jayakody and Wijayanayake [18]. Like Lwakatare [27] stated that DevOps is not a silver bullet since it creates challenges such as the accumulation of technical debt and difficulties in achieving full automation in infrastructure management. After confirming those challenges, Lwakatare et al. [36] observed difficulties in balancing the speed and quality of developments, insufficiencies in infrastructure automation, DevOps skills and knowledge, and valuable metrics for measurements as considerable challenges of DevOps. The study's findings by Raj, P., and Sinha, P. indicate that DevOps impacts an organization's scope, quality, and project management [37]. Azad and Hyrynsalmi have recently confirmed the DevOps adoption issues [38]. Their research indicates that issues with pipeline execution, debugging, feature releases, integrating new standards, and collaboration with clients arise with DevOps adoption in the industry. These studies point to the importance of controlling challenges while getting hold of the benefits of DevOps. Formal adoption of DevOps helps software development companies to attain this target. So, it is required to comply with the critical success factors of DevOps to attain a victorious DevOps adoption.

2.3 Critical success factors for DevOps adoption

Ghantous and Gill [33] identified the critical success elements of DevOps [39] as communication and collaboration, continuous delivery, automated pipeline, quality assurance, continuous deployment, continuous planning, and rollback code by a systematic literature review. According to their findings, communication, collaboration, and continuous delivery are the highest reported conceptual elements by the other researchers. According to Lwakatare [27], the critical fields of DevOps include four primary directions: the culture of collaboration, automation, services & quality assurance. Similarly, Erich has discussed [40] other categorizations for the DevOps success factors as: a culture in which development and operations people regularly interact, automating steps required for this collaboration, measurements that span the discipline of development and operations, and metrics that provide development personnel access to measurements used by operations personnel and vice versa, Lean for optimizing the interaction between development and operations people, and sharing opportunity that development and operations personnel interact.

A systematic literature review by Leite et al. [41] presents the CAMS as the most recognized model for enabling DevOps. This model provides an idea about the critical success factors of DevOps as culture, automation, measurement, and sharing. Again CAMS has been presented as the core value of DevOps by Jha and Khan [42], and Aljundi [43]. As same as the CAMS model, researchers have discussed the CALMS framework, which adds Lean principles to the same CAMS framework. Lean principles motivate continuous improvements by accepting failures as everyday operations.

Furthermore, Amaradri and Nutalapati [9] have explained that software development companies should adopt the principles of culture, automation, collaboration, measurement, and sharing for the success of DevOps practices. In another way, a recent article [29] focused on five critical success factors that help drive DevOps to success. They advised connecting the siloes culturally as the first success factor. The other four considerations are closing the loop between monitoring and planning, measuring the success based on the entire system, keeping practical goals, and leveraging technology to automate and orchestrate. Besides, Yu and Guerra have explained [20] the core requirements for a successful implementation of DevOps practices as: cultural shift, automaton, ability to form multi-skilled groups, top management support, continuous observation, continuous monitoring, start small and iterate. According to them, a cultural shift is the most critical element, and automation is also a key factor for DevOps adoption. Jabbari et al. conducted another literature review [23] to study the DevOps principles. According to their findings, knowledge sharing, automation, shared responsibility, continuous activity, measurement, and composability are essential to achieve the success of DevOps adoption.

Furthermore, Dumoulin has published [44] critical success factors for DevOps adoption: the term DevOps understood by the team, the organizational structure includes the product owner's role, which priories the work based on business value, Cross-functional DevOps team, focus on security in DevOps, the scope expanded with non-functional requirements, continuous integration & deployment, and Use DevOps metrics. Similar to this study, another survey conducted by INTLAND software [45] presented critical success factors for DevOps as service and product ownership, cross-functional team, use of DevOps to bolster security, DevOps Continuous Integration (CI)/Continuous Deployment (CD) of automation toolset, monitoring and Key Performance Indicators (KPIs). Recently, Azad and Hyrynsalmi published nearly 100 DevOps critical success factors as their findings by systematically reviewing 38 research papers [46]. These 100 individual factors are grouped into technical, organizational, and social & cultural factors. Besides, the report published by Akbar et al. [47] identified and prioritized nineteen DevOps access factors and grouped in into three categories as people, business, and change. The people category emphasizes culture more than the tools, empowerment, cross-functional team, skilled DevOps team, and attempt matrix organization and transparency. The next category, business, consists of six success factors; design of a common baseline, sequencing of the DevOps approach, internal DevOps events, demonstration of lean leadership behavior, continuous integration and deployment, measuring progress and planning next improvement. The last category also consists of eight factors; use modeling, integration of changes in operations and support, automated testing, accommodating the legacy system, use of system orchestration, assessment of DevOps strategy, real-time feedback, and DevOps security pipeline. Like most other researchers, this study also ranked cultural changes first. Correspondingly, Ebert and Hochstein explained that according to the perspectives of software operators, culture and discipline are significantly impacted by DevOps practices [11].

Correspondently, Nagarajan and Overbeek [48] have published a DevOps implementation framework for financial organizations. According to them, successful implementation of the DevOps approach in organizations that practice the Agile methodology depends on four factors: organization, people, process, and technology. Organizational factors include organizational structure, large-scale agile practices, leadership commitment, training and guidance, and a trusted environment. People should be competent with cross-functional skills, teamwork ability, communication and collaboration skills, and attitudes to take responsibility. The next factor they presented is the process, which involves continuous process improvement, good knowledge management practices, and operations management practices. Moreover, the last factor identified by this survey is technology. Successful implementation of DevOps depends on continuous software engineering practices and automation. Similarly, Burrell [49] has explained that DevOps adoption capability positively affects organizational agility. Alike, the capability of communication, monitoring, measurement, and automation positively affect the DevOps adoption capability, and the capability of responsiveness, competency, flexibility, and quickness affect organizational agility capability.

According to the majority of explanations by researchers, collaborative culture is the core factor for successful DevOps adoption. Again, different studies have explained diverse ways to attain this collaborative culture within the DevOps team. Luz et al. [50] have presented six main concepts which strengthen the collaborative culture; the development team should seamlessly perform operations tasks, software development empowerment, product thinking, straightforward communication, shared responsibility, and blameless context. More than the collaborative culture, they have presented two other categories that support DevOps adoption as automation and sharing & transparency. The findings of a survey conducted by Lwakatare et al. [51] explained collaboration and culture as two crucial success factors of DevOps adoption. Rethinking and reorientating roles and teams in software development and operations activities is described as collaboration & empathy, support & a good working environment between development and operation teams described as an excellent cultural practice. Govil et al. [52] have defined DevOps as a cultural change in the software development and operations teams. Masombuka and Mnkandla [53] have developed a DevOps collaborative culture acceptance model to explain the importance of the collaborative culture for the success of DevOps adoption. According to them, four elements are crucial to DevOps's collaborative culture. The first element is open communication, which keeps all the DevOps team members informed about the software product through its life cycle. The second element they reported is responsibility and incentives, which align with four main areas as scope, behavior, performance evaluation, and consequences of not fulfilling responsibilities. Next, an essential element described as trust is the willingness of the group to make themselves vulnerable to other groups based on vulnerability, confidence, benevolence, reliability, competence, honesty, and openness. The final element is respect for each member of the group.

Furthermore, in the way of explanation by Smeds et al. [54], DevOps adoption depends on the flourishing cultural change, which includes shared goals and definition of success, shared ways of working and responsibility, collective ownership, shared values, respect and trust, effortless communication and continuous learning. An empirical study [55] conducted by Rowse and Cohen described cultural changes made by DevOps as: giving the responsibility for the development team to deployment functions, quality assurance functions, and deployment operations, more outstanding communication between development and operational functions, attending operational representatives to the planning and development meetings, and aware development team members about the operational faults.

More than the collaborative culture, "automation" is also highlighted by many researchers as a critical factor for the success of DevOps adoption. Luz et al. [50] explained that automation is vital to ensure the transparency, and responsibility of tasks, reduce the risk of human failures, and increase confidence in the team. They have discussed eight concepts regarding automation as; deployment automation, test automation, infrastructure provisioning automation, infrastructure management, autonomous service, containerization, monitoring automation, and recovery automation. As same as Lwakatare et al. [51] also explained infrastructure and deployment process automation as a success factor for DevOps adoption. Not only that, Smeds et al. [54] presented seven concepts as the technological enablers for DevOps adoption. It consists of build automation, test automation, deployment automation, monitoring automation, recovery automation, infrastructure automation, and configuration management for code and infrastructure.

Based on the research conducted by Luz et al. [50], transparency and sharing are essential to disseminating information among DevOps team members. They have identified three main sharing concepts as; knowledge sharing, activity sharing, and process sharing. According to Lwakatare et al. [51], monitoring and measurement are also vital for the success of DevOps adoption. Not only that, Smeds et al. [54] describe the required capabilities for adopting DevOps successfully. According to their explanation, continuous planning, continuous & collaborative development, continuous integration & testing, continuous release & deployment, continuous infrastructure monitoring & optimization, continuous user behavior monitoring & feedback evaluation, and service failure recovery without delay are essential for the success of DevOps practices.

Similarly, a case study-based research conducted by Trigo et al. [56] mentioned top management support as the most mentioned success factor of DevOps adoption. In total, they presented twelve success factors: applied technology, change management, communication, competencies of the involved human resources, cooperation, implementation process, monitoring and evaluation, organizational culture, project governance, project management, top management support, and training of the involved stakeholders. More than the cultural and technical capabilities, Joby [57] has explained the skills very essential for the ideal DevOps team members as: advisory skills, complete stack development skills, analysis skills, functional skills, social skills, decision-making skills, and testing skills to earn the targeted success of DevOps adoption.

2.4 DevOps frameworks presented by other researchers

Few researchers have published frameworks based on the critical success factors of DevOps. Luz et al. [50] presented a model which provides initial guidance for companies to adopt DevOps. As their findings, the most critical factor in DevOps adoption is 'Collaborative Culture.' 'Automation' and 'Sharing & Transparency' propitiate the foundation of a collaborative culture. 'Agility' and 'Resilience' are the DevOps outcomes that expect this formation's consequences. Finally, 'Continuous Measurement' and 'Quality Assurance' are present as DevOps enablers. Not only that, Wahaballa et al. [58] explained that high collaboration between software developers and the operating team might cause conceptual deficits forced by unimplemented non-functional requirements, bounded rationality, complex and dynamic environment, principle agent problems, and moral hazard. They have introduced a unified DevOps with three sub-models: application and data model, workflow execution model, and infrastructure model. More than that, Lwakatare [27] has grouped DevOps practices into two categories: organizational and socio-technical. The organizational perspective focuses on reorienting responsibilities between software development and operating teams, and the socio-technical perspectives focus on automating the software delivery process.

This explanation indicates that some studies have been published supporting crucial success factors and DevOps frameworks. The majority of studies, however, used the literature review approach to identify best practices and, as a result, did not validate those success factors with the current practices of the industry. Moreover, researchers have observed that DevOps practitioners refrain from engaging with available frameworks since they do not directly focus on all the critical success areas of DevOps adoption. As well as, according to Mohammad et al. [59], usage of those frameworks is minimal and needs to be validated by actual DevOps experts. Accordingly, more research and empirical studies are required to guide the successful DevOps adoption with managing the recorded DevOps challenges. Therefore, the requirement of comparing already published critical success factors with the industry expert’s opinion has emerged. Furthermore, it highlights the necessity of a validated conceptual model with improving existing DevOps frameworks which can apply to the successful adoption of DevOps in the software development industry.

3. Research methodology

The grounded theory approach was applied to survey the critical success factors of DevOps, which helped to adopt DevOps in software development companies successfully. This approach is mainly applied in qualitative research using the inductive approach [50]. Based on that, two sequential steps were applied to achieve the aim of this research, as shown in Fig. 1. First, the study used a systematic literature review (SLR) to collect secondary qualitative data. The findings of the SLR were applied to propose a conceptual model which guides DevOps practitioners to earn their success [26]. As the next step, the study applied interviews to discover the experience in DevOps adoption, collecting the primary qualitative data. The results of the interviews were applied to shape the conceptual model developed by the systematic literature review.

Fig. 1. Research methodology

3.1 Identify critical success factors of DevOps through a systematic literature review.

The literature review study was conducted by a systematic mapping research method. It helps to survey the state of the art of research areas that still need to be mature [60]. According to this method, search terms formed as “DevOps”, “DevOps” AND “Evolution”, “DevOps” AND “Software Development Methodologies”, “DevOps” AND “Benefits” OR “Advantages”, “DevOps” AND “Challenges” OR “Problems”, “DevOps” AND “Overcoming Strategies”, and “DevOps” AND “Critical Success Factors”. The search resulted in 317 relevant publications such as journals, books, reports, articles, and conference proceedings from different databases such as Scopus, Google Scholar, Emerald Inside, Web of Science, Science Direct, and Google Search Engine to fulfill the research purpose. Then, the following inclusion and exclusion criteria were applied to select the most relevant publications for this study, and it filtered 223 publications from the downloaded list.

Inclusion Criteria

- Literature discusses the evolution of DevOps.
- Literature discusses Software Development Methodologies.
- Literature discusses the benefits of DevOps adoption in Information Systems.
- Literature discusses the challenges of DevOps adoption in Information Systems.
- Literature discusses the overcoming strategies of DevOps challenges.
- Literature discusses the critical success factors of DevOps.

Exclusion Criteria

- Literature not related to the purpose of the study.
- Inaccessible literature.
- Duplicated literature.

Afterward, the title of downloaded papers was used to filter 201 publications that were more related to the research objectives. As the next step, keywords and abstracts of those selected papers were reviewed, which helped filter the final set of the most relevant 103 studies for the review. Finally, the study was conducted by reading the entire paper of the most relevant 103 studies selected from this systematic approach, as shown in Figure 2.

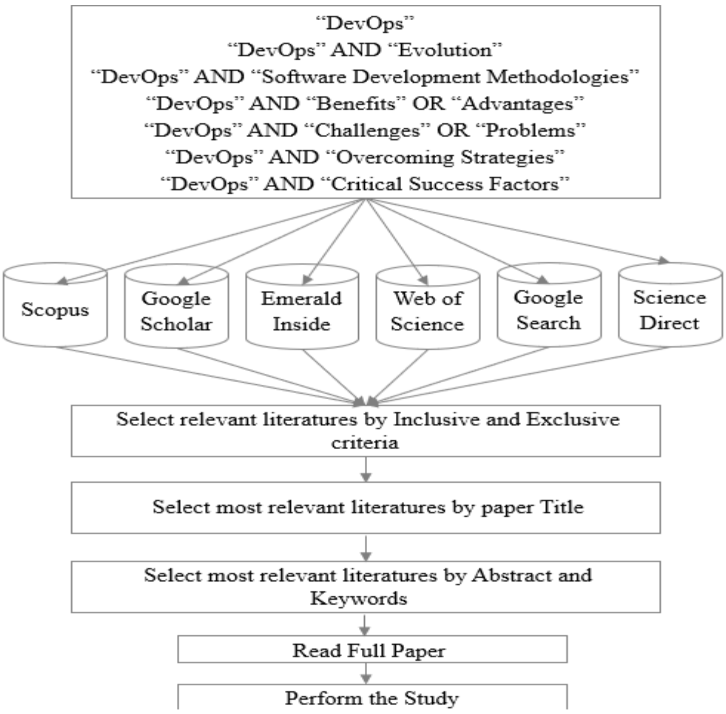

Fig. 2. Approach for the systematic literature review

The systematic literature review study observed background information about DevOps, its evaluation, its advantages compared to the other software development methodologies, and the challenges of adopting DevOps in the software development process. By reading and analyzing this background information, the study identified significant factors to focus on for a successful DevOps adoption in Information Systems. Finally, SLR identified the most frequent critical success factors in studies. This helps to answer the first research question while creating a roadmap to develop a conceptual model for successful DevOps adoption.

3.2 Enhance results of the systematic literature review through the opinion of DevOps practitioners.

As the next step, the research confirmed and identified critical success factors with the actual opinion of software developers by conducting interviews. Semi-structured questions were applied to interview DevOps experts in software development companies. Twelve (12) DevOps experts representing different domains comprised the study sample, as listed in Table 1.

Table 1. Interviewee Details

Interviewee	DevOps Role	DevOps Experience	Age	Gender
A	Senior DevOps engineer	5 Years	35	Male
B	Performance test engineer	3 Years	33	Male
C	Quality assurance engineer	3 Years	31	Male
D	TechOps Engineer	2 Years	30	Female
E	Associate Tech Lead	2 Years	29	Male
F	Automation architect	2 Years	28	Male
G	Software Developer	2 Years	31	Female
H	DevOps Tech lead	1 Year	29	Male
I	Software Developer	1 Year	28	Male
J	Quality assurance engineer	1 Year	27	Female
K	Trainee DevOps	Six months	25	Male
L	Trainee DevOps	Four months	25	Female

Two of the twelve interviews were conducted in person, and the rest online. The findings of the interviews were applied to identify patterns and connections among the collected data. Lastly, an operationalization process used the above-verified results to identify concepts, variables, and indicators of successful DevOps adoption. This helped to answer the second question of this research. Further, the survey results were applied to rank and identify DevOps adoption's most significant critical success factors in Information Systems. In conclusion, the study proposes a conceptual model that helps DevOps practitioners apply DevOps practices and earn benefits by minimizing the challenges.

4. Research findings

Initially, the systematic literature review examined the critical success factors of DevOps adoption identified by the related studies. It was conducted by reading nighty-eight (98) related studies. Among those selected studies, few authors have directly discussed the critical success factors of DevOps and presented these factors in different ways. More than those few studies, other researchers have presented about DevOps practices. The study filtered critical success factors by analyzing their findings and discussions. Finally, this study mapped identified critical success factors and ranked them according to the frequency of each factor identified by previous studies, as shown in Table 2.

Table 2. Critical success factors of DevOps identified by systematic literature review

No	Critical success factors of DevOps adoption	Identifies literature
01	Collaborative culture of the development and operations team supportive and good working environment shared goals and definition of success shared ways of working and responsibility collective ownership and shared values effortless and open communication continuous learning blameless context trust, vulnerability, confidence, benevolence, reliability, competence, honesty, and openness of group members respect for each group member	[1],[9],[14],[11],[23],[27],[36],[39],[40],[41],[42],[43],[47],[46],[48],[49],[50],[51],[52],[53],[56],[57],[61],[62],[63],[64],[65],[66],[67],[68],[69],[70],[71],[72],[73],[74],[75],[76],[77],[78],[79],[80], [81],[82],[83],[84],[85],[86],[87]
02	Automation DevOps CI/CD automation toolset automated testing build automation test automation deployment automation monitoring automation recovery automation infrastructure automation configuration management for code and infrastructure technological enablers	[1],[9],[14],[11],[27],[36],[39],[40],[41],[42],[43],[45],[47],[46],[48],[49],[50],[54],[56],[57],[61],[63],[64],[65],[68],[69],[71],[88],[89],[90],[73],[74],[76],[77],[78],[81],[82],[83],[84],[91],[87]
03	Metrics and Measurements monitoring the progress and planning the next improvement use DevOps metrics use Key Performance Indicators	[1],[9],[14],[23],[40],[41],[42],[43],[44],[45],[47],[49],[56],[57],[61],[63],[69],[71],[81],[82],[86],[88],[92],[93],[94],[95]
04	Continuous Process and Capabilities continuous planning continuous process improvement continuous and collaborative development continuous testing continuous delivery continuous deployment continuous release continuous integration continuous infrastructure monitoring and optimization continuous user behavior monitoring and feedback evaluation service failure recovery without delay	[14],[15],[23],[39],[44],[47],[46],[48],[54],[61],[63],[64],[70],[72],[90],[73],[74],[75],[96],[94],[77],[95],[91],[97],[98]
05	Transparency and Sharing knowledge sharing shared responsibility	[1],[9],[23],[27],[39],[40],[41],[42],[43],[47],[50],[51],[57],[68],[69],[71],[82],[99],[100]

No	Critical success factors of DevOps adoption	Identifies literature
06	Skills of the DevOps team members communication skills advisory skills full stack development skills analysis skills functional skills social skills decision-making skills testing skills cross-functional skills team working ability collaboration skills attitude for taking responsibility. capability of responsiveness competency flexibility	[39],[47],[48],[49],[57],[68],[70],[79],[80],[100],[95],[97],[98],[101],[102],[103]
07	Cross-functional DevOps team	[44],[45],[47],[46],[61],[101],[75],[100],[79],[83],[84],[87]
08	Commitment of the leadership	[48],[56],[66],[67],[69],[76],[80],[85],[86],[102]
09	DevOps knowledge, training, and guidance	[44],[48],[56],[61],[75],[76],[86],[93],[98]
10	Focus on DevOps security	[11],[44],[45],[47],[46],[66],[68],[89]
11	Focus on quality assurance	[27],[39],[46],[64],[92],[95],[98]
13	Real-time customer feedback	[47],[46],[90],[94],[76],[14],[98]
14	Lean and lean leadership behavior	[1],[11],[40],[47],[46],[66]
15	Large-scale agile practices	[14],[11],[48],[63],[95]
16	Organizational structure and scope expanded with non-functional requirements.	[44],[46],[48],[87]
17	Good knowledge management practices	[48]
18	Service and product ownership	[45]

The next and essential part of the research was conducted by analyzing and validating the critical success factors of DevOps adoption using interviews with DevOps experts in the software development industry. Twelve (12) DevOps experts representing different domains comprised the study sample. In numerous respects, as shown in Table 3, they supported the crucial success factors outlined by the SLR.

Table 3. Critical success factors of DevOps identified by interviews

No	Critical success factors of DevOps adoption	Participants
01	Collaborative culture	A,B,C,D,E,F,G,H,I,J,K,L
02	Automation	B,C,D,E,F,G,I,K,L
03	Knowledge about DevOps	A,B,D,F,L
04	Team working skills	C,F,G,J,L
05	Communication	B,H,I,J
06	Continuous delivery	H,I,J,K
07	Continuous integration	H,I,J,K
08	Continuous monitoring	H,I,J,K
09	Continuous testing	I,J,K
10	Knowledge sharing	C,F,L
11	Looking at a problem in a different manner/ Entrepreneurial Ideas	B,G
12	Select the right toolset	A,E
13	Cross-functional team	A, B
14	Multi-functional team	A, B
15	More engagement with the end user	C,K
16	Continuous deployment	I,J

No	Critical success factors of DevOps adoption	Participants
17	Adopting new technologies	B
18	Having the correct idea about the project	A
19	Documenting	C
20	Use DevOps metrics	D
21	Build a good CI/CD pipeline	E
22	Apply security with DevSecOps	E
23	Evolve with project management	E
24	Measurement	F
25	Trusteeship	G
26	Mutual respect	G
27	Integrity	G
28	Security	H
29	Active customer participation	I
30	Integrated configuration management	I
31	Integrated change management	I
32	Automated testing	I
33	Integrated deployment planning	I
34	Improve top-down commitment	K
35	More focus on the KPIs, and it should be transparent	K
36	Soft skills of the team members	L

In the next stage of the research, the critical success factors of DevOps were validated and presented by comparing the literature survey results with the interviews. According to the comparison, most of the success factors have been identified by both literature surveys and interviews, as shown in Table 4. However, interviewees confirmed all the factors identified by the literature survey, and they added two factors that needed to be identified by the literature survey as: applying change-management knowledge and having a clear idea about the project scope. Further, identified critical success factors were mapped into four main areas according to the opinion of DevOps practitioners, as shown in Table 4.

Table 4. Critical success factors of DevOps adoption

No	Critical success factors			Identified in Literature Survey	Identified in Interview
01	Collaborative Culture	I.	Transparency and sharing		✓
		i.	Knowledge sharing	✓	✓
		ii.	Process sharing	✓	
		iii.	Activities sharing	✓	
		iv.	Shared responsibility	✓	
		v.	Shared ownership	✓	
		vi.	Shared values	✓	
		II.	Effective communication		✓
		i.	Effortless communication	✓	
		ii.	Frequent communication	✓	
		iii.	Open communication	✓	
		III.	Management commitment to cultural changes	✓	✓

No	Critical success factors		Identified in Literature Survey	Identified in Interview
02	DevOps practices	I. DevOps technology		
		i. Continuous integration	✓	✓
		ii. Continuous planning	✓	✓
		iii. Continuous & collaborative development	✓	----
		iv. Continuous monitoring	✓	✓
		v. Continuous testing	✓	✓
		vi. Continuous delivery	✓	✓
		vii. Continuous release & deployment	✓	✓
		viii. Continuous process improvement	✓	----
		ix. Continuous infrastructure monitoring and optimization	✓	✓
		x. Continuous user behavior monitoring and feedback evaluation	✓	✓
		xi. Service failure recovery without delay	✓	----
		II. Automation		✓
		i. Automated pipeline	✓	✓
		ii. Build automation	✓	
		iii. Test automation	✓	✓
		iv. Deployment automation	✓	✓
		v. Monitoring automation	✓	
		vi. Recovery automation	✓	
		vii. Infrastructure automation	✓	
		viii. Configuration management for code and infrastructure	✓	
		III. Implement the proper DevOps toolchain	✓	✓
		IV. A balance between human interaction and automation	✓	✓
03	Proficient DevOps Team	I. Multi-functional team	✓	✓
		II. Skills of team members		✓
		i. Communication skills	✓	✓
		ii. Motivational skills		✓
		iii. Organizing skills		✓
		iv. Team working skills	✓	✓
		v. Creativity		✓
		vi. Adaptability	✓	✓
		vii. Cross-functional skills	✓	✓
		viii. Capability of responsiveness	✓	✓
		III. Knowledge and experience in DevOps		✓
		i. The team understands the term DevOps	✓	
		ii. Training and guidance on DevOps	✓	
		iii. Continuous learning	✓	✓
		IV. Lead by a perfect leader		
		i. Leadership skills	✓	----
		ii. Analytical skills	✓	----
		iii. Decision-making skills	✓	----
		iv. Commitment to DevOps changes	✓	✓
		v. Advisory skills	✓	----
		vi. Practice knowledge management experience	✓	----
		vii. Practice change-management knowledge	----	✓
		V. Celebrate success in gaining adoption	✓	----
		VI. Large-scale agile practices	✓	----
		VII. Establish joint accountability for outcomes	✓	----
		VIII. Emphasize culture more than the tools	✓	----
		IX. Respect and trust	✓	✓
		X. Blameless context	✓	✓

No	Critical success factors		Identified in Literature Survey	Identified in Interview
04	Metrics and measurements	I. Clear scope	----	✓
		II. Clear goals	✓	✓
		III. Measure progress and plan the next improvement	✓	✓
		IV. Quality assurance	✓	✓
		V. Security measurements	✓	✓
		VI. Use KPIs	✓	✓
		VII. Develop a roadmap with incremental maturity	✓	✓

5. Results and discussion

The study aimed to analyze the use of DevOps approach in software development by exploring the critical success factors of DevOps in Information Systems. A systematic literature review and interviews with DevOps practitioners were applied to achieve the research purpose. Finally, we proposed a conceptual model, as shown in Fig. 3 for the best practices of DevOps, which help and guide software development companies to earn their victory with a successful DevOps adoption.

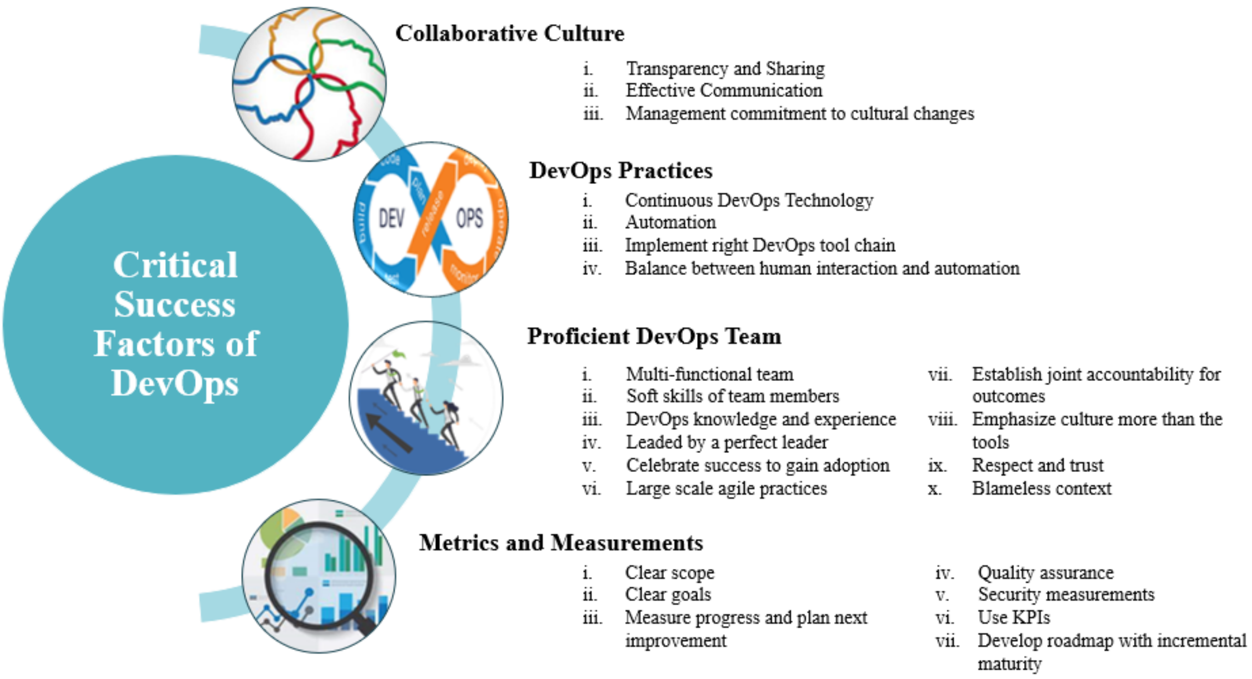

Fig. 3. Conceptual model for the critical success factors of DevOps adoption

According to the literature study and all the DevOps practitioners who participated in the interview, building a collaborative culture is DevOps adoption's main critical success factor. Adoption of a new set of tools is simple when compared to changing the culture of the software development working team [62]. Because culture represents the different opinions of the people, they are different from each other, and the DevOps team combines software developers and operators. Therefore, most related studies discuss enabling collaborative culture as the critical challenge the DevOps teams face, and industry experts confirm it. According to the findings, collaborative culture is related to three success factors: transparency and sharing, effective communication, and management commitment to cultural changes. Both literature surveys and interviews identified these three factors. However, minor aspects were discovered by the SLR and grouped with professional industry opinions. According to that, transparency and sharing consist of knowledge sharing, process sharing, activity sharing, shared responsibility, shared ownership, and shared values. Effective communication can be enabled by open, effortless, and frequent communication. Management or leaders' commitment to change is also critical for building a collaborative culture.

Good DevOps practices are the next essential group of concepts for a successful DevOps Adoption. It combines DevOps technology, automation, the suitable DevOps toolchain, and a balance between automation and human interaction. DevOps technology explains continuous practices of the software development life cycle [77]. SLR is supported in identifying sub-factors of DevOps technology, and most of those factors are also mentioned by industry experts. It consists of continuous planning, continuous integration, continuous monitoring, continuous testing, continuous delivery, continuous release & deployment, continuous infrastructure monitoring & optimization, continuous user behavior monitoring & feedback evaluation. More than that, three sub-factors as: continuous & collaborative development, continuous process improvement, and Service failure recovery without delay, were identified only by the SLR and validated by interviews. Like DevOps technology, automation is also crucial to effective DevOps adoption [77]. Automation can expand to an automated pipeline, build automation, test automation, deployment automation, monitoring automation, recovery automation, infrastructure automation, and configuration management for code & infrastructure. These eight sub-factors were also identified by the SLR and validated by the interviews. Accordingly, software development companies have to automate the software development process based on their practices, called Automated Pipeline. The success of DevOps operations depends on how they build and operate their automated pipeline. While automation considers as a key DevOps success factor, SLR has been confirmed and validated by experts as it is required to maintain a proper balance between this automation and human interaction. Selecting and implementing a suitable DevOps toolchain is also crucial for successful DevOps operations. Many DevOps tools are available for different purposes, and no researchers or DevOps practitioners defined a specific tool as the best. Selection of the correct tool depends on the context. However, according to the interviewees, commonly used DevOps tools can be listed as; "Jira", a team collaboration tool, "Git", a version control system tool, "Docker", a containerization tool, "Puppet", a configuration management and application deployment tool, "Selenium", a continuous testing tool, and Visual Studio Team Service.

Similar to the collaborative culture and DevOps practices, the Proficient DevOps team is the next critical concept for DevOps adoption. Surveys confirmed that the DevOps team must be multi-functional and combine people from the different functional areas of the Software Development Life Cycle. Team members must be skillful with soft skills such as; communication, motivation, organizing, team working, creativity, adaptability, cross-functional skills, and capability of responsiveness. As with soft skills, team members need to fulfill the knowledge and skills in DevOps. This could be observed from both surveys, and SLR provided three sub-factors as: understanding the DevOps concept, training & guidance on DevOps, and continuous learning. The interviewees also validated them as critical factors for the DevOps team members.

Similarly, industry experts validated an SLR finding; a leader must lead the DevOps team with leadership, analytical, decision-making, advisory, commitment to changes, and knowledge management experience. More than that, interviewees suggested improving the team leader's change management knowledge. As same as, SLR perceived and confirmed by the interviewees to celebrate success to gain adoption, establish joint accountability for outcomes, emphasize culture more than the tools, and large-scale agile practices are essential factors for a proficient DevOps team. Also, both surveys confirmed that it is essential to maintain a respectful, trusting, and blameless environment for sustaining a successful DevOps team.

According to the survey results, metrics and measurements are the next important concept for successful DevOps adoption. Well-communicated goals are grouped under this concept. Like developing a roadmap with incremental maturity, measuring progress and planning the next improvement are also crucial for applying the DevOps approach. Similarly, quality assurance, security measurement, and using Key Performance Indicators (KPIs) to measure performance are also identified as critical factors of DevOps adoption and grouped under the metrics and measurements. Both SLR and interviews identify all these factors. However, industry experts added a clear scope of the software development project to this category. These four concepts presented with the conceptual model of the DevOps critical success factors provide direction to software developers for earning the benefits of DevOps adoption while managing the challenges created by the DevOps practices.

6. Conclusion

DevOps is a trending approach for increasing the success of IS developments. It combines IS development and operations teams while delivering high quality products early to the customers. Most IS development companies practice Agile software development methodology for developing their software. It has become more popular since it facilitates adapting to rapidly changing customer requirements. However, the difficulties of installing software in the real environment the software operating team faces highlight the importance of communication with the operating team in the development process. DevOps keeps one front step by introducing an operator who can support the transmission between software and implementation into the software development team. Currently, DevOps is introduced as a new approach to the Agile software development methodology while attracting the attention of software development companies since it delivers more advantages to them. DevOps confirms the faster development, quality assurance, and easy maintenance of the information systems, tackling challenges created by the Agile software development methodology. However, software development companies have recently reported the challenges of adopting DevOps. It is critical to control the challenges while getting hold of the benefits of DevOps for proper adoption of DevOps. This can be achieved by focusing on the critical success factors of DevOps. These industry experiences are not frequently surveyed and reported by many researchers. Existing evidence indicates that the critical success factors surrounding adopting DevOps must be defined appropriately. It is, therefore, essential to study the DevOps critical success factors according to the practitioner's point of view, which helps to face the DevOps challenges. The study aimed to analyze the use of DevOps approach in software development by exploring the experimental critical success factors of DevOps for the prosperity of IS.

A systematic literature review method was applied to identify the critical success factors of DevOps. The identified success factors were compared with the practical software development environment by conducting interviews with DevOps practitioners. Finally, the research presents a conceptual model for the critical success factors of DevOps approach. The conceptual model presents critical success factors of DevOps by grouping them into four areas as: collaborative culture, DevOps practices, proficient DevOps team, and Metrics & Measurement. The study contributes to the literature by presenting critical success factors for DevOps adoption by comparing theoretical knowledge with the practical experience of the industry. For practitioners, the study helps to get DevOps benefits while minimizing its barriers through the proper application of DevOps approach in the software development industry. Researchers can continue the study for further comparisons of these findings with industry experts. The study has several limitations, given that DevOps is a new idea in the software development industry. Lack of studies about the best practices of DevOps. Finding DevOps expertise from various fields in the software development sector proved difficult. Twelve DevOps experts were interviewed for the study, and additional interviews with DevOps specialists could further complement the study's conclusions. Furthermore, future studies are recommended to analyze the maturity levels for DevOps critical success factors that occur between software development stages to promote the acceptance of DevOps in IS development processes.

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Appendix A. Interview Protocol

Step 1: Welcome the interviewee

Step 2: Describe the interviewer in detail

Step 3: Give details regarding the study
Purpose of the study
Present state of the research

Step 4: Gather data about the interviewee
Organization of the interviewee
Role of the present position
Experience in the software development
Experience in the DevOps team
Age

Step 5: Gather responses to the structured questions
How would you describe DevOps?
How DevOps is helpful to software developers?
How DevOps is helpful to software operators?
What are the popular tools for DevOps?
What are the key aspects or principles behind the DevOps?
How would you describe the functions of an ideal DevOps team?
How would you take our company’s DevOps strategy to the next level?

Step 6: Dialogue for additional remarks and inquiries
Discuss about the critical success factors gathered from the literature review

Step 7: Appreciation to the interviewee

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International Journal of
Information Systems and Project Management
ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X
Available online at ijispm.sciencesphere.org

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Information Systems and Project Management
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Available online at ijispm.sciencesphere.org