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# IJISPM



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## Mission

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.

The journal content provides relevant information to researchers, practitioners, and organizations, and includes original qualitative or qualitative articles, as well as purely conceptual or theoretical articles. Due to the integrative and interdisciplinary nature of information systems and project management, the journal may publish articles from a number of other disciplines, including strategic management, psychology, organizational behavior, sociology, economics, among others. Articles are selected for publication based on their relevance, rigor, clarity, novelty, and contribution to further development and research.

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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The journal offers comprehensive coverage of information systems management and project management.

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- information technology governance
- information systems planning
- information systems design and implementation
- information technology outsourcing
- enterprise architecture
- information systems governance
- information systems department
- chief information officer role
- information technology leadership role
- chief information officer skills
- information systems management tools
- management of complex projects
- audits
- innovation
- ethics
- benefits management
- project environment
- project management life-cycle
- project initiation
- project planning
- 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
- quality management
- procurement management
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- communication management
- human resources management
- performance teams
- social aspects
- conflict management
- managing organization - responsibilities
- project management office
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Special issues focused on important specific topics will be evaluated for publication.

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## Correspondence and questions

All correspondence and questions should be directed to João Varajão (Editor-in-Chief). E-mail: editor.ijispm@sciencesphere.org

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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 fourth number of the twelfth volume of IJISPM. In this issue, readers will find important contributions on project management skills and learning methods, digital carbon footprint, risk management and management of changes in projects.

The first article, “Soft skills and learning methods for 21st-century project management: a review”, is authored by Jason Kearney, Taryn Bond-Barnard and Ritesh Chugh. This article addresses a notable gap in the literature by investigating the crucial soft skills required by project management students, graduates, and new practitioners entering the contemporary workforce. The literature review study adopts a concept-centric approach to examine the essential soft skills and effective learning methods for new project managers in the 21st century. Five essential 21st-century project management soft skills (communication, leadership, interpersonal, teamwork and emotional intelligence) were identified, along with three learning methods (experiential, active and reflective) that can be used to develop them. The implications of this research extend to project management students, graduates, and educators alike, emphasizing the importance of nurturing the identified soft skills. As the project management landscape evolves, the findings underscore the need for an education that prioritizes hands-on learning and reflective practices, enabling emerging project managers to excel in their roles and drive project success.

The title of the second article is “Small business, big footprint: the digital carbon footprint dilemma in small and medium-sized enterprises”, which is authored by Ágnes Sándor and Ákos Gubán. According to them, a major contributor to climate change is the emissions from Information and Communication Technology (ICT) devices and digitalization. Energy use, heat production, and the operation of assets all contribute to the production of harmful emissions. However, indirect emissions, such as production and disposal, also play a role. This paper focuses on the emissions of small and medium-sized enterprises SMEs. Is it certain that cloud services (remote data storage and management) leave a much smaller carbon footprint than ICT devices for their own use? These two solutions lead to a paradox: using more modern devices to produce less emissions requires more energy and generates more heat. This article analyses how to resolve this paradox for SMEs.

The third article, authored by Sucheta Lahiri and Jeff Saltz, is entitled “The need for a risk management framework for data science projects: a systematic literature review”. According to the authors, many data science endeavours encounter failure, surfacing at any project phase. Even after successful deployments, data science projects grapple with ethical dilemmas, such as bias and discrimination. Current project management methodologies prioritize efficiency and cost savings over risk management. The methodologies largely overlook the diverse risks of sociotechnical systems and risk articulation inherent in data science lifecycles. Conversely, while the established risk management framework (RMF) by NIST and McKinsey aims to manage Artificial Intelligence (AI) risks, there is a heavy reliance on normative definitions of risk, neglecting the multifaceted subjectivities of data science project failures. This paper reports on a systematic literature review that identifies three main themes: Big Data Execution Issues, Demand for a Risk Management Framework tailored for Large-Scale Data Science Projects, and the need for a General Risk Management Framework for all Data Science Endeavors. Another overarching focus is on how risk is articulated by the institution and the practitioners. The paper discusses a novel and adaptive data science risk management framework – “DS EthiCo RMF” – which merges project management, ethics, and risk management for diverse data science projects into one holistic framework. This agile risk management framework DS EthiCo RMF can bridge the current divide between

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normative risk standards and the multitude of data science requirements, offering a human-centric method to navigate the intertwined sociotechnical risks of failure in data science projects.

“Project Change Canvas” is the fourth article and is authored by Raquel Ferreira, João Varajão, Luís Silva Rodrigues and Rui Dinis Sousa. Project management plays a critical role in boosting the success of organizations’ projects. However, no matter how well a project is managed, changes are inevitable during its execution. It is crucial to evaluate the impact of these changes before implementing them to ensure they do not compromise the project’s success. Existing techniques for assessing the effects of changes have several limitations—particularly in their failure to account for how changes might affect various aspects of project management, such as scope, cost, time, resources, communication, risk, procurement, or overall success. This article introduces a new technique – *Project Change Canvas* – that enables the systematic assessment of changes in information systems and technology projects by identifying and weighing their potential impacts across all relevant project management knowledge areas.

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 Editor,

Nilton Takagi

*Federal University of Mato Grosso*

*Brazil*

Nilton Takagi is a professor at the Computing Institute of the Federal University of Mato Grosso. He is also a researcher at the ALGORITMI/LASI Center. His current research interests are project management (addressing information systems, success management, and the public sector) and business process management. He has a Ph.D. in Technologies and Information Systems, a Master’s in Informatics, an MBA in Project Management, and a graduate degree in Computer Science. In private companies and public institutions, he has held positions as PMO director, IT manager, ERP development team manager, and project manager. He was responsible for various communications and was the author of several publications in the PM and IT/IS area.

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# Soft skills and learning methods for 21st-century project management: a review

**Jason Kearney**
Department of Engineering & Technology Management, University of Pretoria
Lynnwood Rd, Hatfield, Pretoria, 0002
South Africa
jfkearney1@gmail.com

**Taryn Bond-Barnard**
Department of Industrial Engineering, Stellenbosch University
145 Banghoek Street, Stellenbosch, 7600
South Africa
tarynbarnard@sun.ac.za

**Ritesh Chugh**
School of Engineering and Technology, CML-NET & CREATE Research Centres, Central Queensland University
120 Spencer Street, Melbourne, Victoria 3000
Australia
r.chugh@cqu.edu.au

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# Soft skills and learning methods for 21st-century project management: a review

**Jason Kearney**
Department of Engineering & Technology Management, University of Pretoria
Lynnwood Rd, Hatfield, Pretoria, 0002
South Africa
jfkearney1@gmail.com

**Taryn Bond-Barnard**
Department of Industrial Engineering, Stellenbosch University
145 Banghoek Street, Stellenbosch, 7600
South Africa
tarynbarnard@sun.ac.za

**Ritesh Chugh**
School of Engineering and Technology, CML-NET & CREATE Research Centres, Central Queensland University
120 Spencer Street, Melbourne, Victoria 3000
Australia
r.chugh@cqu.edu.au

**Abstract:**
This article addresses a prominent gap in the literature by investigating the crucial soft skills required by project management students, graduates, and new practitioners entering the contemporary workforce. The literature review study adopts a concept-centric approach to examine the essential soft skills and effective learning methods for new project managers in the 21st century. Five essential 21st-century project management soft skills (communication, leadership, interpersonal, teamwork and emotional intelligence) were identified, along with three learning methods (experiential, active and reflective) that can be used to develop them. The implications of this research extend to project management students, graduates, and educators alike, emphasising the importance of nurturing the identified soft skills. As the project management domain evolves, the findings highlight the need for an education that prioritises hands-on learning and reflective practices, enabling emerging project managers to excel in their roles and drive project success.

**Keywords:**
soft skills; learning methods; project management; education; competencies.

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## 1. Introduction

Following the COVID-19 pandemic, organisations are encountering difficulties adapting to a rapidly evolving landscape characterised by heightened competition, interconnectedness, and diversity as they strive to regain the momentum witnessed before the outbreak [1]. This context has added momentum to a project-oriented trend (coined projectification) that has increased the importance of projects and project management [2, 3]. Project management (PM) is necessary for competitive advantage and success [4]. Even though projectification is increasing in organisations, projects continue to fail [5]. For this reason, organisations and researchers continue to focus on investigating and identifying the sources of project success [5, 6].

A substantial volume of literature indicates that project management competencies significantly influence project success [7]. Project management competencies are a popular topic in the literature, as practitioners can easily relate to and understand the implications of this topic in their work environment [7]. This interest is not going away, as is evident by the worldwide demand for project management roles and certifications [8]. The certifications are usually based on a competency standard such as the Project Management Institute's [9] "Project management competency development framework" or the Association for Project Management's [10] "APM competence framework", amongst others. These standards and the sustained focus on this topic in the literature suggest an extensive but fragmented list of competencies [5] with different levels of importance depending on which industry and project type one is interested in [7].

Navigating the vast array of project management competencies can be daunting for project managers or team members. As such, it becomes crucial to identify the most vital competencies for project management students and graduates as they enter the workforce [11]. The project management-oriented labour force is expected to grow by 33% or nearly 22 million new jobs by 2027 [9]. It is important to create this awareness by identifying the important PM soft skills graduates require. In both theory and practice, it has become evident that relying solely on technical project management competencies is no longer enough to ensure project success. This realisation has increased interest among organisations and project practitioners in soft/transferable skills.

Various terms are used to describe soft skills, but they all emphasise the importance of human interaction and social dynamics in various settings, including project management. Such soft skills include effective communication, commitment, leadership, teamwork, negotiation, conflict resolution, and fostering positive relationships [4]. These skills are critical for navigating interpersonal interactions and achieving success in professional settings. Moreover, employers seek graduates with strong soft skills, such as working well in teams, dealing with interpersonal conflict, and solving complex problems [12]. A lack of self-awareness results in new graduates lacking the soft skills organisations seek [7]. Furthermore, it is crucial to recognise that time management and scope management skills include a blend of technical and soft skills. While they entail technical aspects such as scheduling and defining project boundaries, they also require effective interpersonal interaction and communication. Therefore, they can be deemed essential soft skills for successful project management. For instance, the International Association of Project Managers [54] categorises time management as a soft skill, and Millholan [55] similarly places time management under interpersonal skills. Ultimately, the effectiveness of a project might be compromised if certain competencies of the project manager are either absent or underutilised [56].

Over two decades ago, studies conducted by Jaafari [13] highlighted a distinct disparity between project management education and its practical application in real-world scenarios. Remarkably, the disparity continues to persist [14, 15]. To bridge the gap effectively, it is imperative to review and align project management education and training in both industry and institutes of higher learning [7]. Identifying the essential soft skills that graduates need for 21st-century projects is a crucial first step. However, determining the most effective learning methods for imparting these soft skills to new project entrants is equally vital. By focusing on both aspects, comprehensive and targeted approaches can be developed to equip future project managers with the necessary skills and knowledge to thrive in the modern project management landscape. Project management in a hypercompetitive and globalised world requires a range of competencies and approaches; therefore, education should at least ensure that essential PM competencies are in place

[16]. To foster the development of essential soft skills required by 21st-century project managers, it is imperative for pertinent PM stakeholders to embrace appropriate resources, strategies, and methods in PM education and training.

The intention is to fill the identified gap by focusing on project management students, graduates and new project managers. In this vein, the soft skills new project managers require to enter the workforce effectively should be identified, along with the methods to learn those skills in the current digital age. Therefore, this review will focus on the newer generations currently entering the project management workforce: Generation Y (born between 1981 and 1996) and Generation Z (1997 to 2012). Accordingly, this review explores what soft skills are essential for modern projects. Furthermore, it explores what learning methods and techniques are most appropriate for developing these project management soft skills. We will specifically address the following research questions (RQ):

*RQ 1*. What soft skills are essential for project management students and/or new graduates entering the 21st-century workforce?

*RQ 2.* What learning methods can be used to develop the identified project management soft skills?

The responses to these questions facilitate an examination of gaps and deficiencies within the literature, thereby enabling a critical evaluation of project management education and training. Furthermore, the responses will allow for the identification and elucidation of relevant considerations in order to enhance the aforementioned areas of study. This review paper makes a theoretical contribution by highlighting the soft skills that graduate project managers require to be effective in contemporary projects. In addition, it outlines how graduate project managers can acquire or develop these skills in educational settings. The following sections present the research method, results, and discussion. Finally, we conclude by outlining the study's limitations and providing avenues for further research.

## 2. Research method

Systematic reviews are considered the gold standard among reviews and are valuable for identifying, collecting, evaluating, synthesising and critically analysing research literature to answer predetermined research questions [17, 18]. In systematic reviews, data that fits pre-specified inclusion criteria are used to answer the research questions, and the synthesis is typically in a narrative format [17, 19]. Consequently, the inclusion and exclusion criteria (see Table 1) were determined to ensure that relevant literature was shortlisted. In light of the influx of Generation Y and Z individuals entering the project management workforce, it was decided only to include papers from 2010 to 2021 to ensure articles about 21st-century project management students or new graduates are included in this review. In addition, since project management is a multi-disciplinary field, any industry requiring project management was included in this review.

Table 1. Inclusion and exclusion criteria

| | **Inclusion criteria** | **Exclusion criteria** |
|---|---|---|
| **Topic** | Soft skills required for project management; soft skills learning and teaching in project management | Technical project management skills; hard skills learning and teaching in project management |
| **Publication** | Full-text and peer-reviewed journal articles and conference papers | Book chapters, editorials and letters |
| **Date** | 2010-2021 | Before 2010 |
| **Language** | English | Others |
| **Population** | Project management students or graduates (sample population born after 1980).<br>Project managers with less than five years experience by 2000. | Sample population born before 1980.<br>Project managers with five+ years experience by 2000. |

Five literature sources [ScienceDirect, Web of Science, ERIC (EBSCOhost), IEEE and Google Scholar] were searched using relevant keywords relating to the research questions. For example, "project management", "soft skills", “generation z”, “generation y”, “21st century”, “competencies”, “learning”, and “methods”. These short-tail keywords were combined using Boolean operators to form long-tail keywords. For example, “project management AND soft skills” and “learning project management AND soft skills AND generation z”. The keywords were combined to form a list of nine search terms (“project management” AND soft skills; “graduate “project manager” soft skills; student AND “project management” AND 21st century; new AND “project manager” AND competencies; 21st century AND “project management” AND soft skills; “project management” AND generation difference AND soft skills; learning AND “project management” AND soft skills; “project management” AND learning OR methods AND soft skills; and “project management” AND 21st century AND learning). These search terms helped determine what soft skills are essential for project management students or new graduates and what learning methods can develop those skills. As such, articles relating to project management soft skills are included, yet soft skills development in other fields is excluded.

The literature was screened based on the title, abstract, methodology and result sections or equivalent. Relevant articles were identified in three stages, first by their titles, second by their abstract, and finally, screened based on the full text. An adaptation of the PRISMA flow diagram [20] was used to record key metrics of the screening and selection process (see Figure 1).

The quality of each article was determined by its ability to answer the research questions (relevance) and how the study was designed, conducted, and reported (rigour). The method and results sections of the articles were examined closely for relevance and meaningful answers to the research questions. Finally, 29 articles (24 journal articles and 5 conference papers) were shortlisted for analysis.

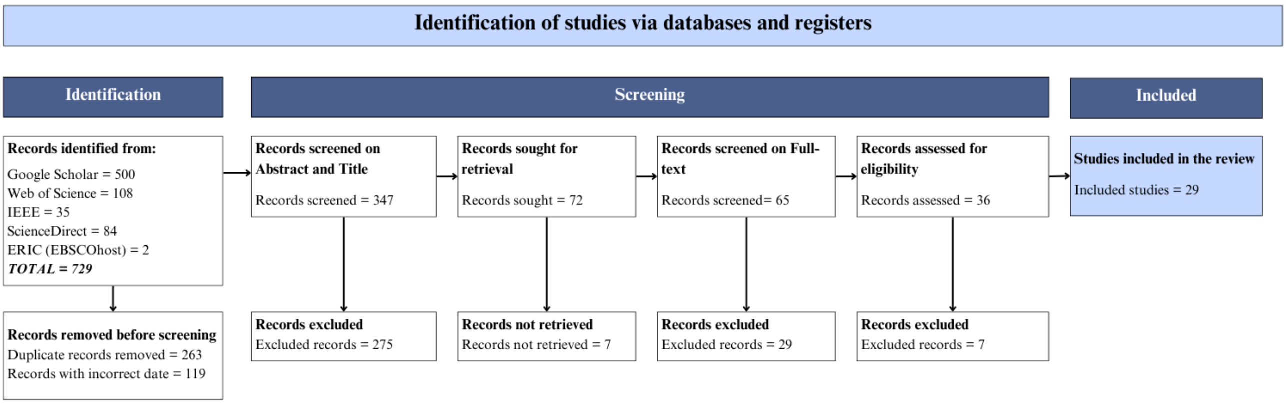


Fig. 1. Screening and selection PRISMA flow diagram

Concepts were generated during the data extraction phase by independently coding prevalent themes in each study. Next, the main concepts from the articles were clustered into two concept matrices, based on the code groups, first to identify the project management soft skills and, secondly, the methods to learn the project management soft skills. Finally, the findings of the studies were categorised based on their relevance to answering the research questions. The next section outlines the literature review findings using a concept-centric approach.

## 3. Results

The two main categories of the literature review results are *project management soft skills* and *soft skills learning methods*. The categories provide insight into answering the research questions. Based on the results obtained from the concept matrices, the concepts in each category are reported in decreasing order of study mentions.

*3.1 Project management soft skills*

As illustrated in Figure 2, eighteen project management soft skills were identified from the shortlisted literature. The most prominent soft skills mentioned by more than 50% of the shortlisted literature include communication, leadership, interpersonal skills, and teamwork. However, of all the soft skills identified, communication skills were mentioned the most, with 76% of the articles including communication as an essential project management soft skill.

The fifth soft skill, emotional intelligence, relates to other soft skills such as empathy, self-management, conflict management and interpersonal skills, as discussed by Zhu et al. [21] and Magano et al. [22]. The thirteen remaining soft skills, excluding the abovementioned skills, were mentioned by less than 30% of the literature. However, these soft skills are often cited as part of, or reliant on, the five most prominent soft skills mentioned above. Hence, while our main focus is on the five primary soft skills, the other soft skills have been woven into the discussion, and their relevance is outlined in the following subsections.

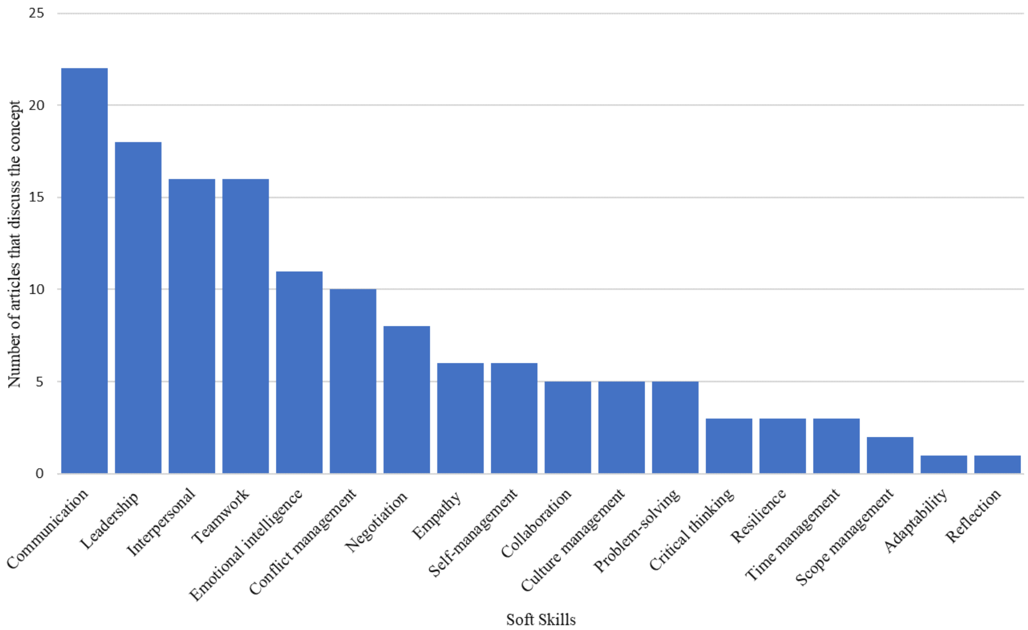


Fig. 2. Soft skills identified in the literature review

*3.1.1 Communication skills*

Communication, in the context of project management, is multi-faceted and includes oral, written, informal, formal, internal (within the project), external (other stakeholders), vertical and horizontal [4]. Effective communication is the process of exchanging accurate and appropriate information with team members and stakeholders using suitable methods [23] to express one's opinion and listen to others [24]. Project managers require communication skills to meet the information management demands of team members and various stakeholders [25]. Industry 4.0 project management soft skills are significantly transformed, mainly by promoting new ways of communicating and interacting with stakeholders and team members [26]. Therefore, students need to communicate effectively, utilising technology, to meet the needs of the 21st-century job market [12, 26, 27]. With the advent of new communication technologies, project management students can benefit significantly by developing their communication skills, especially in digital formats such as writing reports and e-mails [12].

Using the correct terminology or “project management language” is necessary for project managers to communicate their intent effectively to team members and stakeholders [28]. Therefore, project management course providers must embed the language of project management into the course to better comprehend its meaning in practice. However, Magano et al. [7] found communication, organisation and team spirit to be strengths of Generation Z students. These strengths also have an impact on teamwork and group interaction. These results are promising for project management since practitioners find communication to be one of the essential soft skills to possess [7, 29]. Moreover, effective communication skills are required for group interactions to be successful [7, 29] by encouraging teamwork, avoiding mistakes and reducing non-productive efforts [4]. Group interactions may include dealing with conflicts, different opinions, team member participation and the division of work between members. Therefore, communication skills are required in many project contexts, along with other important soft skills such as leadership, negotiation, conflict management and teamwork [4].

Communication skills help develop interpersonal relationships since talking to team members informally can help the project manager uncover their feelings. The project manager must also use active listening skills to communicate effectively [30]. In the study by Musa et al. [12], 86.2% of students indicated that their communication abilities were enhanced by focusing on active listening skills when interacting with group members. Similarly, Alvarenga et al. [4] found that practising project managers believe that communication is an essential soft skill for project success and rank it as the most important soft skill to possess. Tian [31] also found that communication is the second most important soft skill project managers can have in the 21st century, followed by verbal skills. In contrast, a study by Connolly and Reinicke [32] found that only 66.7% of project management students believed that effective communication was essential to their career and ranked it as the fourth most important soft skill. Ballesteros-Sanchez et al. [33] found that the communication competency gap between project managers and students is 8%, which is significant. Ramazani and Jergeas [34] also found that project management graduates lack the communication competencies to enter the workforce. These studies emphasise the need to improve student communication skills to succeed in the project environment. However, Luţaş et al. [35] found that project management certifications are more valued in the hiring process than communication skills.

*3.1.2. Leadership skills*

Leadership skill is among the top three project manager competencies perceived by practising project managers for the successful delivery of projects [4]. Liikamaa [24] found that leadership competency was evaluated as the highest among practising project managers. This self-assessment dealt with the project manager’s ability to act reasonably towards others and motivate the team.

Leadership comprises a set of soft skills that cannot be learned through formal methods [36]. Instead, leadership is developed over time with experience. Project leadership is the act of motivating, inspiring and guiding project team members and stakeholders. The goal of leadership is to manage and deal with issues effectively to achieve the project objectives [23]. A project manager’s leadership skills are a critical factor affecting project performance [37], and leadership is the most vital soft skill for project management [31].

Leaders apply interpersonal understanding (empathy) principles to better understand team members’ needs and take practical actions, leading the team to achieve the project objectives [37]. Therefore, leadership is closely related to other soft skills such as interpersonal relationships, negotiation and teamwork. In particular, project managers should lead by example, display appropriate levels of self-confidence and know when not to act authoritatively to lead others effectively [30]. According to Shelley [28], decision-making experience and social interactions are required to develop leadership skills. In a study by Zhang et al. [37], project managers in China perceived teamwork and leadership as more critical to a project’s success than stakeholder management and social awareness. Therefore, future project managers must have diverse skill sets. It is also expected that communication, leadership, and technology skills will increase in importance to deliver projects successfully in the 21st century [27].

Similar to communication, Ballesteros-Sánchez et al. [23] found a significant gap (8.7%) between practising project managers and students regarding team leadership. Both Magano et al. [7] and Ramazani and Jergeas [34] found that leadership is a weakness for Generation Z since students had difficulties assigning team roles, delegating tasks and managing responsibilities. However, the younger generation's apparent lack of leadership skills may be remedied by reevaluating the project management education system, mentoring, practice monitoring, and collegial support [34].

*3.1.3. Interpersonal skills*

Interpersonal understanding and relationship management are two facets of interpersonal relationships. Interpersonal understanding is closely related to empathy since it is the willingness to understand others. Interpersonal understanding is the basis for building interpersonal skills since understanding others can build group trust and enable a project manager to work with stakeholders from different backgrounds. Leadership is also closely related to interpersonal understanding since leadership entails understanding others first and treating each team member with consideration and respect [37]. Relationship management refers to a project manager's ability to deal with personal relationships in the project environment between team members and stakeholders [37]. Furthermore, social awareness is another dimension of interpersonal relationships. Social awareness is the project manager's ability to read situations and gauge how others feel.

Therefore, interpersonal skills are the project manager's ability to effectively communicate with team members and stakeholders [38] and build meaningful relationships. In the study by Connolly and Reinicke [32], students ranked interpersonal skills as the second most important soft skill for their careers. Similarly, practitioners perceived interpersonal skills as the second most important soft skill [38]. Alvarenga et al. [4] state that teamwork, perseverance and flexibility form part of the interpersonal relationships skill set.

Project management students need to acquire interpersonal skills to meet the job market requirements in the 21st century [12]. In addition, Zhang et al. [37] found that personal relationships, called *Guanx*i in China, are a vital competency project managers require in the Chinese context. However, interpersonal skills are influenced by the time available for team members and the project manager to interact [31]. Therefore, interpersonal conversational skills are needed in the 21st century since shorter, high-paced meetings are an emerging trend [31]. Fisher [30] mentioned that project managers must acquire insight into their team and stakeholders' feelings, beliefs, and values. Through authentic behaviour, project managers can develop greater interpersonal relationship skills, which benefit other skills such as negotiation, conflict management, leadership and culture management skills.

*3.1.4 Teamwork skills*

Alvarenga et al. [4] identified teamwork as one of the 28 most important soft skills for project managers. Tahir [39] found that team-building is among the three most influential skills required for project success. Teamwork and cooperation are fundamental project management skills that are necessary to work and cooperate with team members and other stakeholders [37]. Managing team dynamics is a significant challenge for project managers in the 21st century [27]. Project managers face multiple challenges in managing teamwork, particularly in virtual teams. Effective teamwork management is a fundamental skill in project management, requiring the ability to motivate and guide the project team while staying focused on the project objectives [26]. This skill is essential for successful project outcomes and highlights the importance of developing teamwork expertise for project managers.

Team involvement is an inherent characteristic of project work [7]. Magano et al. [7] and Silva et al. [40] found that Generation Z displays high levels of agreeableness, significantly impacting their empathy and sensitivity to emotions. These traits are closely linked to project management soft skills such as teamwork and team-building [22] and can be improved with appropriate training and counselling [39].

The study by Connolly and Reinicke [32] showed that 77.8% of project management students felt that team-building skills are one of their career's most important soft skills and ranked it third after critical thinking and interpersonal skills. 89.3% of students indicated that effective teamwork contributed to successfully completing a 12-week project-based learning process [12]. However, the study conducted by Ramazani and Jergeas [34] shows that project management students do not have the necessary communication and teamwork skills required by industry. Therefore, there is a disconnect between what the industry requires and what traditional education systems provide regarding teamwork skills [7].

### *3.1.5 Emotional intelligence skills*

Emotional intelligence is the ability to understand and manage the emotions of others as well as your own emotions in the project environment. Borg and Scott-Young [41] state that emotional intelligence is the ability to use this emotional awareness to manage relationships and the behaviour of stakeholders. By applying self-management, social awareness and relationship management, project managers can become more aware of their own and others' emotions in the project environment [42].

Zhang et al. [37] state that the emotional intelligence of a project manager includes both emotional competencies and social intelligence. Research found that students who display traits such as extraversion, agreeableness and high levels of consciousness tend to have higher degrees of emotional intelligence [22, 40]. In addition, a positive correlation between emotional intelligence and agreeableness exists [7]. This association may foster other soft skills like teamwork and interpersonal relationships.

Project managers require emotional intelligence to control their own emotions, as well as those of stakeholders and team members, in such a way as to avoid irrational behaviour and reduce conflict. Therefore, conflict management skills are closely related to emotional intelligence since the project manager can align stakeholder interests with the project goal by managing conflict and the associated emotions [37]. Project managers require adequate stress-handling skills, as stress can cause conflict in a project environment. A study by Ballesteros-Sanchez et al. [33] found that conflict management is the most significant soft skills gap between practising project managers and students.

However, it was found that with higher levels of project complexity, the impact of the project manager's emotional intelligence on project commitment is reduced [21]. With increased project complexity, the project manager bears additional pressure from stakeholders and team members. Once the emotional resources of a project manager with high emotional intelligence are depleted, they may engage in withdrawal or evasion to avoid conflict and project commitment [21]. They also found that a project manager's emotional intelligence positively affects project performance and commitment. By being aware of emotions, the project manager may also affect the stakeholder's attitudes towards a project. Emotional intelligence contributes towards 70% to 80% of project management success [25]. Although emotional intelligence is an intrinsic characteristic of an individual, Magano et al. [7] state that it can be developed through adequate experience and training. In addition, Magano et al. [7] found that Generation Z project managers have a high degree of resilience and a medium degree of conscientiousness, which presents a significant positive correlation to emotional intelligence.

### *3.2 Learning methods for soft skills*

Project managers are required to display a mixture of technical management skills, leadership and interpersonal competencies [31]. Therefore, project management educational methods and programs should equip project managers with the skills to enter the 21st-century workforce [31].

Generation Z is often described as an individualistic generation reluctant to participate in teamwork [40]. However, in the 21st century, teams are becoming more common, and the need for good teamwork is imperative. Therefore, project management teaching methods should promote social interaction and communication by embedding teamwork in educational activities [40]. Ballesteros-Sanchez et al. [33] found a significant gap between students and practising project managers in terms of conflict management, emotional management, leadership and communication competencies. There is a need to overcome this gap in their soft skills by utilising educational approaches that motivate, engage and take advantage of the younger generation's ability to use technology [22].

There are various educational approaches to overcome the soft skills gap between practising project managers and students. Some of these educational approaches focus on active learning and experiential learning [40], while others focus on reflective learning to retain or enhance the learner's understanding of soft skills. Six soft skills learning methods (see Figure 3) were identified, which are discussed under the three main concepts (experiential, active and reflective learning) in the following subsections. The remaining approaches (project-based, game-based, and role-play learning) form part of these three main methods. For example, experiential learning includes project-based learning and game-based learning, and active learning includes role-play learning.

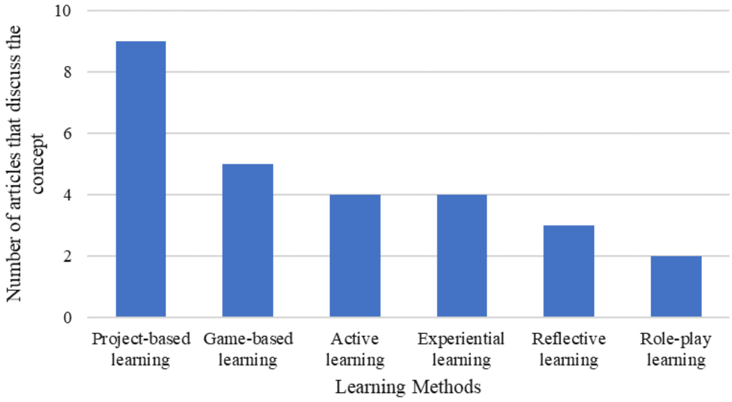


Fig. 3. Project management soft skills' learning methods

### *3.2.1 Experiential learning*

It is imperative to enhance project management teaching methods to enable Generation Z students to smoothly transition from higher education institutions to the workforce and equip them with the essential skills for the 21st-century project environment [7].

Teaching methods such as hands-on projects, computer simulation, role-playing and project-based learning approaches are more suited to Generation Z's traits [7]. Experiential learning is the simulation of real-life company environments to enhance the students' ability to communicate and collaborate in an actual project, which is not always possible through traditional teaching methods [43]. Experiential learning engages the learners through project tasks such as leading, scheduling, stakeholder management, and communication.

Project-based learning (PjBL) motivates individuals to partake in activities such as teamwork, social interactions, team creativity and alternative forms of verbal and non-verbal communication, such as presentations and body language [22, 40]. In the study by Connolly and Reinicke [32], students who completed the course reported higher degrees of emotional intelligence, critical thinking and communication skills. Furthermore, de los Rios-Carmenado et al. [44] found that most students who participated in PjBL activities developed teamwork, creativity, leadership, and negotiation skills. Magano et al. [22] found that PjBL is an effective method for building collaboration, teamwork, and communication skills. Musa et al. [12] state that PjBL contributes to soft skills development, which are essential for the 21st-century job market. By structuring teaching methods to accommodate the personality traits of 21st-century students, a greater level of soft skills development can occur since PjBL implementation draws upon existing traits of Generation Z, such as resilience and motivation. The study by Musa et al. [12] also found that upon completing the project, 72.4% of students agreed that they had become more sensitive and perceptive to the needs of their team members and stakeholders. 69% of students agreed they improved their social skills by talking to workers and employers. Therefore, PjBL can also help develop students' communication and interpersonal relationship skills [12]. Ballesteros-Sánchez et al. [23] found that by following the PjBL methodology, cognitive ability and communication ability showed the most significant improvement. Therefore, through PjBL, project management students may learn many highly sought-after skills by employers [12].

Game-based learning is another form of experiential learning where game participants can experience project management in complex situations and experience the daily challenges associated with an interdisciplinary project team [29]. The game aims to improve the technical knowledge and soft skills of participants. In addition, computer simulations include competitive games where students can learn decision-making skills when solving problems without the risk of real project consequences [40]. As Maratou et al. [43] discussed, the three-dimensional role-play game in virtual reality simulates unexpected events during a project, and students are expected to collaborate and interact to manage these events. It was found that participants had a positive experience regarding the game experience and the learning effect it had [43]. Educational games, such as *C2* discussed in Geithner and Menzel [29], and the role-play virtual world outlined in Maratou et al. [43] are more enjoyable than traditional learning methods and more effective for soft skills development. By simulating real-life organisations, games enhance the experiential learning of human-related issues encountered in the project environment, such as team communication, leadership and collaboration [43]. Students can maximise their potential by harnessing their innate ability to use technology while simultaneously honing essential soft skills crucial for effective project management in the 21st century [40].

*3.2.2 Active learning*

Active learning is a learning method that actively engages students throughout the learning process [32]. Active learning involves learner participation through activities such as reading, discussions and writing. Ang et al. [45] found that blended learning through workshops is a creative way of encouraging active learning to engage project management students and helps graduates to be job-ready. Ballesteros-Sánchez et al. [23] found that engineering students can develop essential soft skills such as conflict management, leadership, communication, and emotion management by applying active learning methodologies. Furthermore, Connolly and Reinicke [32] found that project management students are engaged in the learning process by applying active learning methods. These active learning methods included limiting the class to 24 students who met in person twice a week in an active learning classroom (the chairs and tables are modular and moveable), where student-led learning is encouraged through various in-class activities. It was found that this approach improved soft skills such as emotional intelligence and interpersonal skills.

Role-play is an engaging and novel method currently used by institutions of higher learning to teach project management [40]. Through role-play, students can better appreciate the problems encountered in a multicultural project environment. In addition, students have the opportunity to try multiple roles in a project to improve their social awareness and develop skills such as communication, conflict resolution and negotiation from varying perspectives [40]. Role-play may also form part of experiential learning through competitive online games. Due to the recent disruptions to the learning environment, students have been exposed to more self-directed learning [40]. This has profoundly impacted students' learning experience since more classes and group activities had to be conducted online. This trend presents an opportunity to adapt educational approaches to support the discipline of project management in complex and uncertain times [40].

Many project management institutions are already shifting from a lecture-based teacher-centred (instructivist) learning approach to a more workshop-based learner-centred (constructivist) method to maximise student performance and engagement [45]. The shift from an instructivist to constructivist mode can be made by incorporating active learning methodologies into existing project management courses or developing new courses focusing on soft skills development [23].

*3.2.3 Reflective learning*

Reflective learning involves learners thinking about information and understanding things before acting. Reflective learning requires students to write case studies about their own experiences in projects and the possible impacts of their soft skills on the project outcomes. By reflecting on how the theory is applied to project situations, students can better understand how theory can assist their development and aid them in applying soft skills in the future [28]. In addition, by reflecting on their successes and challenges, project managers will be able to solve these problems more successfully in the future and be well-prepared for changing environments [29].

Project management curricula should emphasise reflective practice to better understand empathy's varying dimensions and how it impacts individuals [46]. Without reflective practices, students will not develop the soft skills obtained through other educational approaches, such as experiential learning and active learning [46]. Therefore, project managers who can reflect on their own experiences will develop their capabilities and leverage the capabilities of their project team members in a constructive manner [28].

Reflective learning methodologies may help students develop and retain soft skills learned in educational institutions. Furthermore, reflective learning teaches students reflection soft skills, which enables them to deal better with complex situations [31]. Moreover, with higher levels of project complexity, project managers need to develop critical thinking and reflective practices that go beyond the technical aspects of traditional project management teaching [34].

## 4. Discussion

The literature review suggests that communication, leadership, interpersonal relationships, teamwork, and emotional intelligence are essential soft skills for 21st-century project managers to possess as they impact the project manager’s effectiveness and project success. The learning methods used to develop these project management soft skills found in the literature review are experiential, active, and reflective learning.

One notable contradiction was identified in the study conducted by Connolly and Reinicke [32], where students rated effective communication skills as the least important for their careers. This discrepancy suggests a potential gap between the perceptions of project management students, who consider certain soft skills crucial for their careers, and the views of practising project managers, who prioritise different soft skills as most important for the industry.

The findings of this soft skills review exhibit a noteworthy convergence with existing scholarly literature emphasising the significance of human and social skills. Notably, the vital soft skills identified for 21st-century project managers, namely communication, leadership, interpersonal relationships, teamwork, and emotional intelligence, are consistent with the prevailing literature in the field [4, 7]. Moreover, the review highlights the interconnected nature of these soft skills, revealing multiple interdependencies within project management. These results are well-founded in light of the broader literature base, as these soft skills are integral to a project manager’s capacity to foster professional, personal, and social relationships, necessitating a repertoire of diverse soft skills.

Some studies found other soft skills to be essential as well, such as creativity [31], problem-solving [47] and negotiation [4]. Although these additional soft skills were not found to be one of the essential soft skills in this literature review, it should be noted that soft skill rankings may differ and vary slightly in different fields depending on their relative importance and often participant subjectivity.

The soft skills learning methods review results align with the literature. In the form of PjBL and game-based learning, experiential learning received more attention in the literature than active and reflective learning. However, as previously outlined, each method applies a different approach and has its own unique learning outcomes, advantages and disadvantages. Therefore, the review results support existing literature regarding the success of active forms of education, rather than passive forms, in teaching project-based soft skills [48].

In light of the study by Zhu et al. [21], it becomes apparent that the link between a project manager’s emotional intelligence and project commitment diminishes at higher degrees of project complexity. Consequently, for Generation Z individuals who demonstrate elevated levels of agreeableness and conscientiousness, both of which are associated with emotional intelligence, fostering the soft skill of reflection becomes increasingly vital. By engaging in reflective learning, students can develop their capacity to critically analyse situations, effectively navigating the complexities of 21st-century projects, a concept well-supported by existing literature [49, 50].

## 5. Conclusion

The review carries significant educational implications for both project management students and graduates as they enter the 21st-century workforce, as well as for project management educators who aim to prepare them for the challenges ahead. Notably, the study highlights communication, leadership, interpersonal skills, teamwork, and emotional intelligence as the most critical soft skills for project managers to possess in the modern era.

Furthermore, the findings underscore the value of active educational approaches like experiential learning, active learning, and reflective learning over more passive methods when educating future project managers. Emphasising these active approaches can better equip students with the practical knowledge and critical thinking abilities necessary to tackle the complexities of contemporary projects and succeed in their roles as project managers.

Twenty-nine studies were selected for inclusion in this systematic literature review, following inclusion/exclusion criteria. The implementation of a well-defined search strategy instilled confidence that all relevant research was accounted for in the review. However, despite the thoroughness of the process, this study, like any other, is not immune to limitations. A noteworthy limitation lies in the fact that the researchers responsible for conducting the search process, screening, selection, quality assessment, and coding of full-text articles could have introduced subconscious biases, selection bias, and reporting bias, potentially impacting the overall quality of the review. Furthermore, confounders bias might be present in the literature review due to variations in participant demographics, such as age, educational level, and experience, across the included studies. Nevertheless, the review has a relatively low selection bias because the study participants still align with the target population outlined in the predefined inclusion criteria. It is important to emphasise that the review questions were specifically focused on students or new graduates entering the 21st-century workforce, limiting the scope and applicability of the findings to this particular demographic. This specificity enhances the review’s relevance for project management students and new graduates facing the challenges of the modern job market.

It is encouraging to note that several new studies have been published recently, focussing on soft skills in project management. Rosamilha et al. [51] also determined that communication, leadership, interpersonal relationships and emotional intelligence are the top four most cited ‘soft skill’ competencies irrespective of project type. In addition, in a study of graduate project managers, it was noted that their soft skills were not fully developed [52]. A notable approach in these studies is to prioritise behavioural, management, and organisational competencies using a hierarchical structure. These competencies are often seen as essential for successful project management, particularly in the public sector [53].

Future research should be conducted to assess the relationships between project management soft skill development at an institutional level and outcomes on future performance (in practice). For example, the goal of future research could be to establish an observable link between teaching methods, such as experiential learning, and soft skills, which lead to project success. Another recommendation for future research could be to include a qualitative component in the study. For example, a focus group with project managers from different generations (X, Y, Z) could provide interesting perspectives on the results found in this review.

The world is rapidly transitioning into a digital era, marked by the emergence of transformative technologies like artificial intelligence, machine learning, and bots, which hold the potential to bring significant changes to the project management field. However, even with these advancements, the human side of project management will remain indispensable. Hence, focusing on nurturing students’ soft skills is crucial, as they form the bedrock of effective project management. By adapting educational approaches to leverage the strengths of the younger generation and their familiarity with technology, institutions can equip students with the soft skills needed to navigate the complexities and changes in the project management industry. Emphasising the development of communication, leadership, interpersonal skills, teamwork, and emotional intelligence will prepare future project managers to succeed in this evolving environment.

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## Biographical notes

**Jason Kearney**
Jason Kearney is a Senior Project Manager at Brokkr, South Africa, leveraging his civil engineering degree (cum laude) and an honours degree in engineering & technology management (cum laude) from the University of Pretoria to excel in the mining and material processing industries. His expertise encompasses opportunity identification, program management, technology acquisitions, research and development, and project management. Jason collaborates with multiple project teams across South Africa to design, manufacture, install, commission, and operate lime crushing and screening plants, wet separation plants, and briquette plants. Additionally, his co-founding of DRIP, a company pushing the boundaries of 3D printing with alternative material extruders, showcases his continuous drive for learning, skills development, innovation and project management.

**Taryn Bond-Barnard**
Taryn Bond-Barnard is an Associate Professor in the Department of Industrial Engineering at Stellenbosch University, South Africa. Her qualifications include an engineering degree (cum laude), a Master's (cum laude), and a PhD in Project Management. As a project management expert, her research focuses on the human aspects of project management and project management education. She teaches project management at a postgraduate level and is also the Academic Programme Coordinator for Stellenbosch University's new hybrid online Structured Masters in Engineering Management Programme (https://mem.sun.ac.za/). She has published widely in both national and international journals and regularly presents papers at conferences in her field of expertise. In 2018, she received the International Project Management Association Global Young Researcher Award.

**Ritesh Chugh**
Ritesh Chugh is an Associate Professor in the School of Engineering and Technology at Central Queensland University, Australia. As an information systems socio-technological expert, his research focuses on the social role of emerging information systems and their influence on humans and organisations. He takes an interdisciplinary approach to research, which includes information systems management, social media, project management, knowledge management, educational systems and technology-enhanced learning. He has received several teaching awards recognising his teaching excellence, commitment to improved student outcomes and engagement in reflective learning and teaching activities. Ritesh is a senior member of the Institute of Electrical and Electronics Engineers and the Australian Computer Society. He is also a Senior Fellow of the Higher Education Academy.

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# Small business, big footprint: the digital carbon footprint dilemma in small and medium-sized enterprises

**Ágnes Sándor**
Budapest Business University, Centre of Excellence for Future Value Chains
Markó u. 29-31., Budapest, 1055
Hungary
sandor.agnes@uni-bge.hu

**Ákos Gubán**
Budapest Business University, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
guban.akos@uni-bge.hu

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# Small business, big footprint: the digital carbon footprint dilemma in small and medium-sized enterprises

**Ágnes Sándor**
Budapest Business University, Centre of Excellence for Future Value Chains
Markó u. 29-31., Budapest, 1055
Hungary
sandor.agnes@uni-bge.hu

**Ákos Gubán**
Budapest Business University, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
guban.akos@uni-bge.hu

**Abstract:**
A major contributor to climate change is the emissions from Information and Communication Technology (ICT) devices and digitalisation. Energy use, heat production, and the operation of assets all contribute to the production of harmful emissions. However, indirect emissions, such as production and disposal, also play a role. We rely mainly on the output of small and medium-sized enterprises (SMEs). This paper focuses on the emissions of SMEs. Is it certain that cloud services (remote data storage and management) leave a much smaller carbon footprint than ICT devices for own use? These two solutions lead to a paradox: using more modern devices to produce less emissions requires more energy and generates more heat. This article analyses how to resolve this paradox for SMEs.

**Keywords:**
carbon footprint; SMEs; digitalization; digital emission; ICT emission; emission paradox.

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## 1. Introduction

Climate change is currently one of the biggest problems for the sustainability of life on Earth. It is now clear that the current pattern of economic growth has environmental impacts that threaten the survival of life on Earth. According to the Intergovernmental Panel on Climate Change (IPCC) report 2022, greenhouse gas (GHG) emissions will continue to rise. This was also the case in the decade between 2010 and 2019, when the average annual increase was at its highest, but the rate of increase has now slowed compared to the previous decade [1].

However, Information and Communication Technologies (ICT) now present a fairly positive picture from a sustainability perspective, as they have substantially transformed the way we communicate and work, revealing opportunities to reduce the impact on human nature. For example, e-commerce, teleworking, videoconferencing and Covid-19 have reduced the global movement of people and goods, thereby reducing oil consumption and greenhouse gas emissions [2]. Does the spread of different digital technologies/techniques and innovations really reduce the environmental impact of economic activities?

To ensure sustainable digital transformation, efforts are needed to green digital infrastructure, manage climate risks, and reduce environmental footprints. In the era of digitalisation, data infrastructure such as data centres and cloud solutions are crucial in supporting public management and delivering services efficiently. However, these key elements of contemporary societies come with challenges. They require significant energy, utilize important resources, and add to greenhouse gas emissions. For a sustainable digital transition, it is necessary to focus on making digital infrastructure more eco-friendly, handling climate-related risks, and minimizing environmental impacts [3].

To address these issues, the International Telecommunication Union and the World Bank in partnership with the Federal Ministry for Economic Cooperation and Development (BMZ) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) have developed a practitioner's guide to 'Green data centres: towards a sustainable digital transformation. The guide covers six critical dimensions that practitioners can consider to green data centres:

- climate-resilient data centres;
- sustainable design and buildings;
- sustainable Information and Communication Technology;
- sustainable energy;
- sustainable cooling;
- e-waste management.

These factors should also be included in public procurement strategies and criteria, as well as in broader policies and regulations, to promote investment in environmentally friendly data centres and enhance the resilience and efficiency of existing data centre infrastructure [3].

Hence, the theme of this study is to analyse the paradox that the more advanced, mainly digital, tools are used to reduce emissions (hereafter used interchangeably with emission equivalents), the more energy is needed and the more heat is generated as a result of exploiting the potential of these tools. In other words, as an unintended side effect, mitigation efforts themselves are likely to increase emissions. The related research gap: what are the environmental impacts of the digitalisation of small and medium-sized enterprises (SMEs)?

The aim of the study is to answer the question: can the paradox be resolved, and if so, how and in what direction? On the other hand, it aims to define the framework of a model that can be used to resolve this paradox, based on the results of the available literature, and which is capable of reconciling the current carbon footprint of SMEs with their environmentally sustainable operations.

The focus of the study is on the SME sector and related digitalisation. This is primarily due to the low digital maturity of SMEs and the lack of change in their digital competitiveness [4]. As a consequence, it is crucial that companies adopt the right technology/techniques in their digital transformation with the least possible environmental impact.

SMEs are a special case in terms of emissions, because most of them are not able to adapt modern low-emission technologies and other solutions, which are mainly linked to digitalisation and digital technologies. On the one hand, they do not have sufficient resources to purchase them, and on the other hand, their operation and use do not offer significant economic benefits. By contrast, medium-sized and large companies can afford, and are expected, to include in their strategic objectives the optimisation of emissions, in addition to minimising their carbon footprint. These require very costly up-front solutions and investments, the return on which these types of businesses can incorporate into their long-term economic objectives. A further aim is to enable a wider range of SMEs, accounting for half of EU GDP, to start measuring their digital emissions by resolving this paradox. The importance and timeliness of the issue is underlined by the fact that SMEs account for 63% of total $CO_2$ emissions in the EU [5].

Energy efficient cloud computing has become a priority for the EU. Data centres need to become more energy efficient, reuse waste energy such as heat and use more renewable energy sources in order to become carbon neutral by 2030 [6]. The progression of digital technology in Europe clearly indicates a shift towards edge computing. This practical approach underlines the importance of processing data near its origin, focusing on efficiency and independence [7].

SMEs need an optimisation model that allows them to operate optimally with the lowest possible emissions. The model should be a multi-component and multi-faceted tool, including the functions of the possible and optimal IT/digitalisation tools in terms of emissions and costs, trained on a quantitative scale of values. The set of link functions describing the interaction of these elements is expected to be vector-vector functions. The latter is important because the interactions of some elements can worsen or can improve the individual emission values. In this paper, we do not provide such a model, but rely on the literature to demonstrate that such a model has an exact form and justification. Such an analysis is not to be found in the currently available literature, and this gap filling is a scientifically novel element of the paper.

The Science Direct research database was examined between 2012 and 2022 for the following search terms:

- carbon footprint + SME: 1286 results,
- carbon footprint + digitisation: 9783 results,
- digitalisation + SME: 7258 results,
- digital transformation + SME + carbon footprint: 248 results, of which 170 journal articles.

The narrowed search covers the following topics: environmental sciences, energy, engineering, decision support, management and economics, social sciences, chemistry, computer science, and psychology. Articles on computer science focus on the digital transformation of manufacturing and logistics systems. The papers published in the fields of management and economics focus on the digital transformation of financial systems, blockchain technology and the digital transformation of customer processes. This suggests that there are no studies in the current literature that specifically address the environmental impacts of the digitalisation of SMEs in relation to $CO_2$ emissions.

To justify the existence of a paradox, it is necessary to resolve it, which is exploratory research. This will be answered by an exploratory and deductive approach based on a review of the literature. In our opinion, the justification of the model can later be verified by empirical data.

The paper first introduces the digital carbon footprint paradox and then clarifies the concepts of carbon footprint, carbon emissions and digital emissions. Then discusses the relationship between ICT and the digital footprint, and how the paradox can be resolved for SMEs. The paper concludes with a summary and conclusions chapter.

## 2. Literature Background

### *2.1 Digitalisation and sustainability*

Wireless sensors and monitoring technology have enabled the development of the concept of smart grids, smart homes and smart buildings to optimise energy management in individual rooms by monitoring parameters such as temperature, humidity or sunlight [8], [9]. This of course further complicates the paradoxical situation of emissions. Mobile apps allow customers to measure and reduce their GHG emissions. This improves customer engagement (digital business outcome) and supports sustainability goals such as achieving net zero emissions. The circular economy platform creates new revenue, which translates into business outcomes for both digital business and sustainability [10], [11].

However, the dependence on ICT devices and services is growing rapidly, so the energy needed to produce and operate ICT devices is also increasing significantly. The energy required to produce and operate the ICT devices in use contributes significantly to the formation of carbon dioxide, greenhouse gases and other global warming pollutants [8]. Empirical evidence also shows that despite the energy efficiency improvements in ICTs over the past seven decades, the carbon footprint continues to grow. Large-scale investments and rapid developments are taking place in the ICT sector, which are potentially energy-hungry areas of innovation, including IoT, data centres and cloud computing. These are fuelled by the demand for big data and are also being further boosted by the use of artificial intelligence (AI) techniques for big data analysis [12].

In fact, the domain of sustainability is difficult to define, as the concept is multi- and transdisciplinary and ICT and related innovation affect socio-economic organisations at all levels through actions, decisions and behaviours. Hence, sustainable innovation is only possible if all levels of relevant organisations are involved [13], [14].

When it comes to the sustainability of digitalisation, two different approaches are appropriate. Green by IT is about making processes more efficient and sustainable by introducing IT systems. Greening by IT aims to make IT itself more sustainable. The main building blocks of the digitalisation strategy are data centres (storage, processing) and telecommunication networks (transmission) [15].

Digital sustainability is an organisational activity that seeks to achieve sustainable development goals through the use of technologies that create, use and transmit electronic data. Some of the most commonly used technologies include blockchain, artificial intelligence, machine learning, big data analytics, mobile technology and its applications, sensors and other IoT devices, and other telemetric devices such as satellites and drones [16]. Digital sustainability is the means by which digitalisation can achieve global sustainability goals [17]. In this case, digital sustainability is able to combine the two strategic objectives of sustainability and digital transformation to bring about positive social and environmental change rather than focusing on merely reducing it [14].

According to Ardito et al. [18], there is no evidence that combining digitalisation and sustainability improves firm performance. While there is a generally optimistic view that the use of digitalisation tools is key to sustainability, it is important to be aware that digitalisation can also be a disruptive force, because unintentionally, uncontrolled or underestimated, it can negatively affect sustainability and its development. Ghobakhloo [19] makes a similar observation that in an Industry 4.0 environment, interconnected computers, smart materials and smart machines communicate with each other, interact with the environment and ultimately make decisions with minimal human involvement.

Digital business and sustainable business outcomes can feed each other. The digitalisation of manufacturing and business processes, and the use of smarter machines and tools, can bring many benefits, such as increased manufacturing productivity, more efficient use of resources and reduced waste. IoT, data and analytics can optimise wind turbines, reducing costs (digital business outcome) and greenhouse gas emissions (sustainability outcome). Nevertheless, digital connectivity, information production and sharing as the real strength of Industry 4.0, can have contradictory impacts on the three pillars (economic, environmental and social) of sustainability.

Carnerud et al. [20] concluded that there is a high degree of overlap between sustainability and sustainable development. Quality management (QM) researchers have a positive view of sustainability, as well as of digitisation, but digitisation initiatives are not at the cutting edge of the QM paradigm. This is probably a result of the recent emergence of too many new concepts and technologies in the toolbox for business process re-engineering.

Andriushchenko et al. [21] showed that digital transformation of businesses can be achieved through sustainable development. The mathematical model presented ensures that the risks associated with digitalisation can be anticipated and minimised. This allows the prediction of business activity taking into account the vector of development (digital transformation). Under uncertain conditions, the use of the model helps to ensure the quality of the digital transformation of the business, regardless of the level of development of the company.

The digital transformation brings many benefits, which also have a positive impact on combating climate change and reducing $CO_2$ emissions. However, ICT investment is a significant component of $CO_2$ emissions. It also increases the production, use and data transfer of digital devices and the energy consumption of the internet network (more data centres and servers/routers involved). For example, the energy consumption of the device during streaming results in additional $CO_2$ emissions.

### *2.2 The paradox*

As demand for data centre services grows rapidly, the carbon footprint of these facilities will also grow rapidly if companies do not reduce their environmental impact by increasing energy efficiency and optimising consumption. Fig.1 shows how different ICT trends impact the growth of emissions from data centres, networks and devices, leading to exponentially increasing energy consumption. The number of connected devices is steadily increasing, expected to reach 55.7 billion by 2025, generating huge amounts of data. Data will also need to be stored, further increasing the demand for data centres [22], [23].

To retain customers, storing data in the cloud or seamless data integration forces data centres to operate uninterrupted, so data centres need to use diesel generators as a backup power source. This in turn leads to greenhouse gas emissions and has a significant impact on the climate change. These emissions can be described in terms of a digital $CO_2$ footprint or digital carbon footprint [24]. In addition, heat in data centres needs to be reduced. To address this thermodynamic threat, data centres rely on cooling, which accounts for more than 40 percent of electricity consumption. In addition to cooling, data centres emit acoustic waste, known as noise pollution. This can lead to increased blood pressure and cortisol levels, as well as anxiety [25].

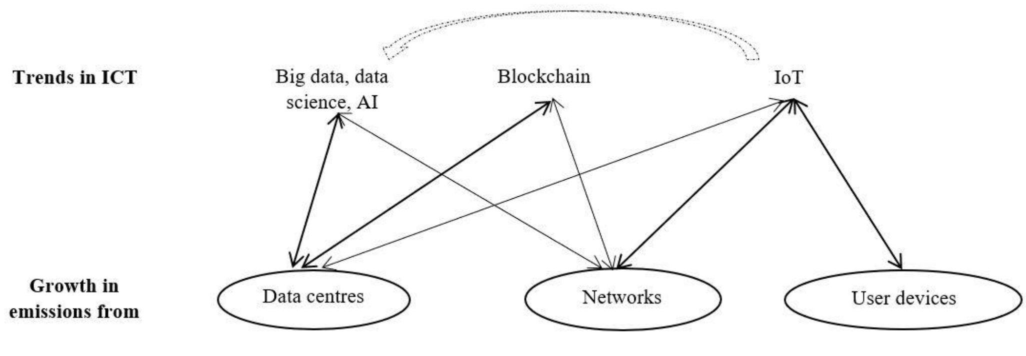


Fig.1. The impacts that trends in ICT have on growth in emissions from data centers, networks, and devices [23]

The preceding finding is reinforced by the Jevons paradox [26], according to which technological improvements that improve the efficiency with which a resource is used, rather than reducing the use of the resource, actually increase it. Economist William Stanley Jevons observed that technological improvements that enabled more efficient use of coal led to greater use of coal in many areas of industry. He says that energy conservation is hopeless because increased efficiency increases demand. Nevertheless, improved efficiency can improve quality of life.

The above shows that although energy efficiency is improving, overall energy consumption is not decreasing. This is reinforced, inter alia, by the rebound effect of working part or all of the time at home, whereby the employee spends the time saved by travelling to work. This results in additional energy use comes from. Thus, business considerations continue to dominate, i.e. firms are using digitalisation not to reduce environmental burdens but to increase sales or reduce costs [27]. Technology is both the source of the problem and the solution. Using the right technologies and techniques can help combat climate change, but this requires taking into account our digital carbon footprint.

According to Blair [12], the following competing factors will determine the future output of ICT devices (Table 1).

Table 1. Factors contributing to future ICT carbon emissions [12]

| | |
|---|---|
| Efficiency | Innovation |
| Renewable energies | Moore's Law |
| Contact | Jevons paradox |

The left-hand column shows a number of factors that can help reduce ICT emissions, starting with increasing efficiency. For example, since the advent of computing, Moore's Law has helped to improve efficiency. To complement this, many sectors of the ICT industry are increasing the percentage of energy from renewable sources. There has been significant progress in data centres, less so in the decentralised internet. There are also important arguments that ICT development is leading to lower emissions in other sectors through improved accessibility [28].

On the right-hand column, many experts argue that the period covered by Moore's Law is coming to an end. Moreover, the effect of the Jevons paradox is often ignored.

The lack of consensus on which technologies should be included in the calculation of ICT GHG emissions makes the calculation of emissions very difficult. Some preliminary estimates do not take into account the full life cycle and supply chain of ICT products and infrastructure. For example, the energy used to manufacture the products and equipment, the carbon cost associated with all their components and the operational carbon footprint of the companies behind them, the energy used to use the equipment (including its availability), and finally the energy used to dispose of it once its purpose has been fulfilled [23]. All digital activities have a carbon cost. However, many companies are not aware of this fact and the level of awareness varies across sectors. The extent is relatively higher in the banking and consumer goods manufacturing sectors and lowest in manufacturing [29].

For example, Gartner Transportation and Logistics recommends that companies try to reduce storage and processing requirements by, among other things, moving from point-to-point to hub-oriented integration patterns and adopting more modern data integration techniques, such as data virtualisation, which do not require data movement.

According to Simon Mingay, Gartner's Vice President of Research, the following principles deserve wider adoption [30]:

- Avoid unnecessary duplication of data, for example by using shared repositories and data virtualisation.
- To achieve analytical goals, minimise the amount of data processed by developing standardised, automated reports based on historical data needs to serve future data needs.
- Storing data on passive media using a tiered approach.

All of the above can show that digitalisation and digital developments will certainly reduce emissions and carbon footprints. However, if a Google search is associated with an average of 0.01 kilograms of carbon dioxide emissions (carbon dioxide equivalent - CO2e) and at least 4.5 billion searches are made worldwide every day, several questions arise. In addition, not only searching Google, but also using a cloud service for several hours a day (including cloud-based mail systems) can result in huge carbon emissions. In this way, the cloud is not only a material force, but also an ecological force. As it expands, so does its environmental impact [31].

It can also be observed that the more advanced an ICT system in an SME, the more services are used that would otherwise not have been used before or at a lower level of development (these tools also have energy requirements and relatively high heat emissions).While only the raw material and production are considered as a factor increasing the carbon footprint when using a paper-based spreadsheet, there are many more components to consider when using a dashboard output via a cloud service with a smartphone.

However, if an SME does not operate its own computer system (server, LAN, printers), does not use applications, data management systems, reporting tools locally, but shares them by using other people's resources, or even sharing its own resources, it can increase utilisation and reduce downtime. This will also reduce your emissions. But digitalisation only contributes to reducing the carbon footprint if it is managed wisely. The IPCC [1] report also notes that there is very little systematic analysis of the impacts that can be expected as the digital economy spreads. What kind of energy consumption will the data centres have? What will be the consumption and lifestyle impact of increasing social media usage, artificial intelligence, blockchain? How will the digital divide between social groups and regions evolve?

In our study, we investigate whether and how the digital paradox in the research question can be resolved, *"For an SME, digitalisation is an emission-reducing factor, while the consequence of digitalisation may be higher harmful emission levels."*

First, we will clarify some basic concepts. In our analysis, we narrow down the set of small and medium-sized enterprises. On the one hand, we exclude sole proprietorships and micro- enterprises (1-5 persons), as well as enterprises belonging to the top layer of the SME sector (hereafter referred to as top SMEs). The reasons for this are explained in the previous chapter. For micro enterprises, the primary operating objective function is the difference between revenue and cost. For top SMEs, the conscious choice of ICT for operations, the use of higher quality equipment, already allows to keep the carbon footprint lower. In between, most SMEs do not incorporate emissions into their operational objective function, and thus do not consider the environmental damage they cause. They do so despite the opportunity to take such considerations into account.

### *2.3 Digital carbon footprint*

The carbon footprint shows how much greenhouse gas is emitted directly and indirectly into the air as a result of a person's lifestyle, a company or community's activities, or the life cycle of a product. The carbon footprint is the total amount of greenhouse gases directly and indirectly caused by an individual, an event, an organisation, a product, expressed in CO2e. The total footprint of an organisation covers a wide range of emission sources, from the direct use of fuels to indirect impacts such as employee travel or emissions from other organisations within the supply chain. A common classification method is to group GHG emissions according to the level of control an organisation has over them [32]. On this basis, there are three main types of GHG classification:

- Direct emissions from activities controlled by the organisation.
- Emissions from electricity use.
- Indirect emissions from products and services not directly managed by the organisation.

The digital carbon footprint is the $CO_2$ emissions from the production, use and transmission of digital devices and infrastructure [22]. Digital emissions are defined as all harmful emissions that can be attributed to ICT and digital development/operation/activities and that negatively affect the carbon footprint.

## 3. ICT and digital carbon footprint for SMEs

According to the Eurobarometer [5] report on SMEs, EU SMEs have already taken significant steps to transform their business towards environmental sustainability. They are predominantly trying to become more resource efficient by using renewable energy, recycling or minimising waste (3Rs: Reduce, Reuse, Recycle). However, compared to 2018, the pace of improvement in their sustainability is slow. Given the significant dynamics of climate change, they need to transform faster. Their combined share of total emissions is also high, accounting for 63% of total $CO_2$ emissions from companies. This makes it essential that the digital transformation of these companies is appropriate, i.e. it does not matter which technologies they will adopt [5]. The situation is complicated by the low awareness within companies of the carbon footprint of their own IT infrastructure, with only a few companies having a strategy to identify this [30].

The defined footprints are heavily influenced by digitalisation on the one hand and ICT tools on the other. It would therefore be useful to define precisely which factors and components have the greatest impact on these two indicators. In our case, we refer to the elements of software, hardware, orgware, peopleware that are related to digitalisation and that play a role in the digital carbon footprint of SMEs.

Perhaps the simplest approach is to start from digital maturity and digital maturity life-cycle [33]. Fig.2 shows the Digital Maturity Technical Architecture (DMTA), which illustrates a possible digitalisation component system.

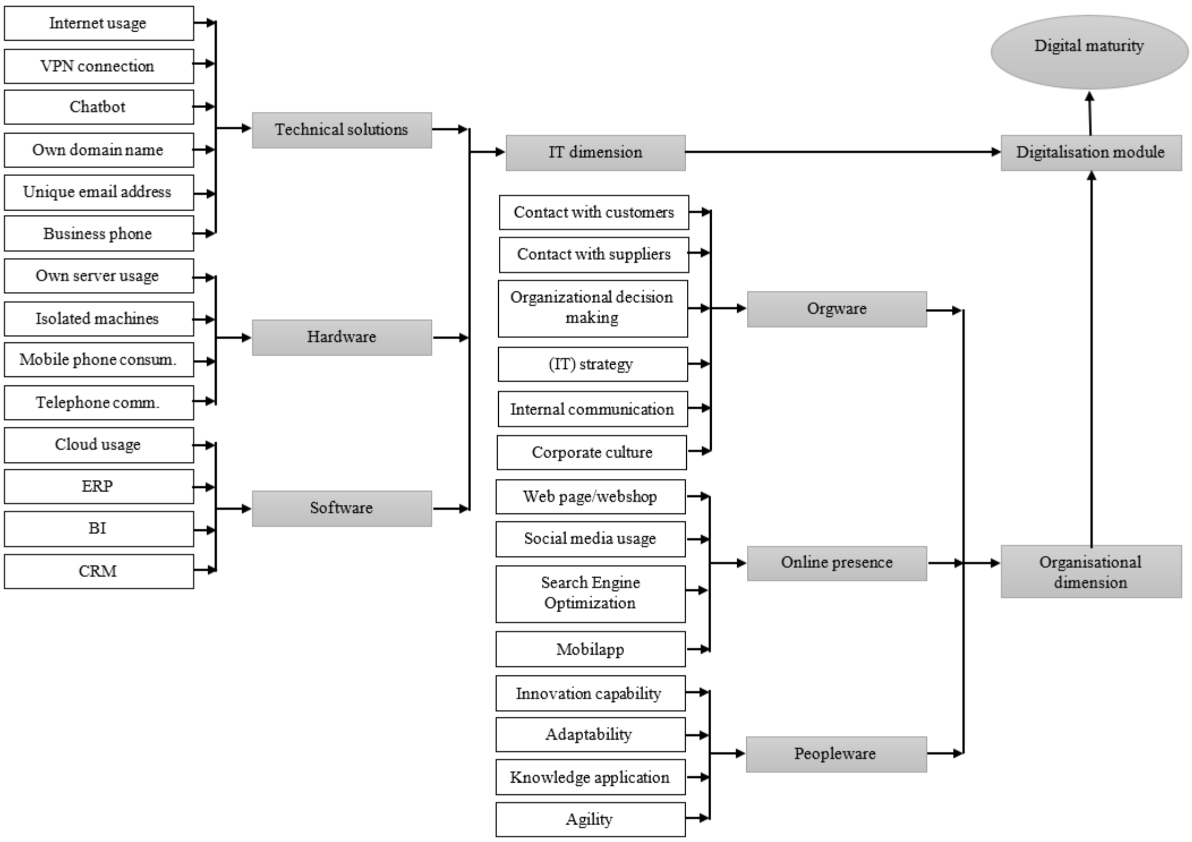


Fig. 2. Framework of Digital Maturity Technical Architecture [34]

In our case, we need to consider which components have a significant digital footprint. It is clear that all components of the technical solutions are important, and it is also clear that they need to be extended. All components of hardware necessary and expansion should be carried out. The software components also need to be extended and restructured. So, the IT dimension plays a significant role. The ICT organisation can be abandoned, its emissions are not significant for digitalisation. The online presence is very important, it does not need to be restructured. Human ICT, like the ICT organisation, is negligible for the purposes of our present analysis. Let us then examine the reconstructed components.

The first component to be recreated concerns technical solutions.

- It is clear that the digital emission of technical components will be indirect. This is important because in such a case the digital emissions are shared among several users and the utilisation of the hardware behind such components is much higher and implies lower emissions per unit of time than using this type of own hardware resource (e.g. no unnecessary energy consumption for stand-by, no amortisation during stand-by, etc.).
- Digital devices are constantly transmitting data over the internet. The relationship between the level of energy consumption of data networks and the amount of data transmitted is very complex. This is due to the constant fluctuations in the amount of data and the which should take into account the peak times with maximum data volumes. However, this relationship can be estimated as follows:

  Energy consumption = transmission duration * time factor + amount of data transmitted * volume factor.

From this estimate, assuming different transmission speeds and data volumes, the greenhouse gas emissions of the data network for the following activities can be estimated as follows [35], [36]:

- Greenhouse gas emissions from data networks,
- 4 hours of video streaming per day: 62 kg CO2e per year,
- Backing up 1 gigabyte per day: 11 kg CO2e per year,
- Internet activity emissions: 1 hour of standard video discussion 270 MB data, 0.008 kWh/GB internet electricity consumption, 321g CO2/kWh emissions.

Examination of the technical components shows that their use is not always environmentally friendly. 24-hour internet can result in an SME using the network even when it is not needed but when availability makes it reasonable (as we have seen, a Google search is equivalent to 0.01 kg of $CO_2$ emissions). While Google previously estimated an average online search to consume 0.3 watt-hours of electricity, roughly equal to driving 0.0003 miles in a car, this figure is probably much higher now due to Google incorporating generative artificial intelligence (AI) models into its search algorithms [37]. Conversely, a device's stand-by mode also uses unnecessary energy, both for standby and for rapid response. It also consumes energy for applications that are not needed. So, on the one hand, a good internal policy can help a lot to plan resources in a way that they can be optimally used, also with respect to extreme loads. If such events occur infrequently and predictably, then it is always advisable to hire and share resources.

The other big problem with technical components is redundancy. As the current data storage policy tends towards virtual data erasure, i.e., data is not physically erased but only logically, a lot of redundant data storage is needed. For example, the ultimate goal is for all of Google's data centres and offices to become carbon neutral by 2030 at the latest [38]. A well-designed cloud application should use only the necessary resources. This is important because when fewer resources are used, it implies that fewer virtual machines operate in a data centre, leading to lower energy consumption and reduced carbon dioxide emissions. Therefore, the initial step in minimizing the digital carbon footprint linked to cloud computing is to structure applications efficiently.

Every time we use AI to generate an image, write an email, or ask a question to a chatbot, it comes at a cost to our planet. The $CO_2$ emissions of digital or AI-based services are less obvious and harder to measure. Indeed, a new study by researchers from the AI startup Hugging Face and Carnegie Mellon University has revealed that creating an image using a potent AI model consumes as much energy as it takes to charge a smartphone fully. Nonetheless, the study also discovered that the energy required for generating text using an AI model is considerably lower. Luccioni and her team investigated the emissions associated with AI tasks available on the Hugging Face platform. Generating images stood out as the most energy- and carbon-demanding task among AI-based activities. On the other hand, the text generation model with the lowest carbon intensity they evaluated produced an amount of $CO_2$ equivalent to driving a similar vehicle for 0.0006 miles [37]. Generative AI models consume a lot more energy because they perform multiple tasks simultaneously like generating, classifying, and summarizing text, rather than focusing on a single task like classification. The latest generation of AI systems consumes significantly more carbon than the ones we used just two or five years ago. For a comparative perspective, it is estimated that during their training, OpenAI's GPT-3 and Meta's OPT released over 500 and 75 metric tons of $CO_2$, respectively. The substantial carbon footprint of GPT-3 can be attributed in part to its training on older hardware, which was less energy-efficient [39]. The most important suggestion is to train the machines in a place where the energy needs can be largely provided by renewable energy sources.

The technology infrastructure supporting net-zero energy data centres will become increasingly modular and demand-driven. For example, cloud and edge computing systems allow data processing and storage to span multiple devices, systems and even multiple locations. For example, a shift to edge computing can reduce energy consumption by processing data closer to the source. This reduces the need to transmit data to a data centre hundreds of miles away.

Yet, there is a method that not only improves online experiences but also supports environmental sustainability - the use of Content Delivery Networks (CDNs). CDN is all about optimising the access time and loading speed of the website, even if you want to access it from a physically remote machine. Computer networks sometimes have to serve huge distances. Usually, we do not think about the exact path that data takes when we type a website address into a browser. CDNs consist of a network of servers, distributed across multiple geographic locations, positioned in a strategic manner. CDNs improve the ability to scale, reduce server loads, and help build a more stable and responsive streaming setup. The careful location of CDN servers cuts down the distance for data travel, leading to swifter delivery of content, less buffering, and better video clarity. Regarding the carbon footprint of video streaming, while it is a matter of concern, it remains comparatively low due to swift advancements in energy efficiency within data centres, networks, and devices. As technology continues to progress, the energy used for streaming video is anticipated to reduce, further emphasizing the significance of CDNs in advocating for digital sustainability [40].

A similar problem exists with electronic mail. A group message with an attachment is always stored in at least one copy in the sender's account (mail server), but also available in at least one copy in each recipient's account, not to mention the private copies downloaded to desktop, phone. This is incredible high energy and resource wastage. With a smart resource solution, a single instance would be sufficient and with shared access - with appropriate security solutions of course - data storage energy and resource requirements can be saved. These are of course only partially passed on to SMEs, but are included in the overall footprint as an indirect footprint.

The use of chatbots is perhaps the clearest benefit from an account manager's ICT perspective. This should include the emissions generated during the commute to and from the workplace, the use of desktops and other ICT devices during working hours, and on-call time. Based on Reyes-garcía et al. [35], the annual commuting per person in the UK is 750 kg $CO_2$ equivalent and in the Netherlands 410-630 kg $CO_2$ equivalent. Conversely, when using chatbots, only the application's standby and operational ICT emissions need to be accounted for, which are much lower emissions than the human solution. (Here, network and individual connectivity energies and emissions need not be considered, as they are the same in both cases.)

5G as a technical component poses an interesting problem. It provides higher quality communication, for SMEs using IoT, it provides much faster and more accurate communication. As it is an important factor of their objective function, its use is essential. As its presence is independent of the SMEs, its use is appropriate, although it will always increase indirect output and be a burden on the SMEs, regardless of their intentions.

So far, there has been no mention of electromagnetic pollution. The non-wired communication devices used (routers, switches, telephones, Bluetooth devices, sensors, etc.) cause permanent electromagnetic pollution. The main problem is that only a very small fraction of the electromagnetic waves propagating in all directions is used. There is more scope for reducing pollution here: the energy from such emissions could be used to charge and power devices, thus reducing the electromagnetic pollution of companies without compromising the quality and speed of data transmission, and reducing the level of $CO_2$ equivalent pollution. The other components are not discussed in detail in this study.

The second and most important emission component is hardware. The problem with hardware components is the high energy demand and the relatively high heat generation, high recycling and high energy and cost requirements and a lot of waste. Therefore, the use of a large number of these components in SMEs requires a high degree of caution. It is advisable to use as few tools as possible, focusing only on those that are essential to the operation. The energy they use will be direct energy for SMEs and the emissions will be direct. Which ICT hardware components are absolutely essential? Generally, one consumerised mobile communication device per person, although if the SME's data security policy allows, these can also be the users' private devices, reducing the number of devices and in this case the utilisation is much higher. This is much more efficient in terms of digital emissions. These devices can replace much more energy intensive desktops, notebooks, etc.

Although it is inconceivable for an SME not to have at least one desktop-like tool, if for no other reason than to perform accounting, bookkeeping and process management tasks. These will not be addressed in the present study, but will be a necessary and important element for the subsequent model.

Many other hardware items, such as servers, printers, specific hardware items, can be used in a shared way in many cases, thus reducing their number. Shared use, in turn, implies greater use of technical components. All digital devices emit $CO_2$ during their use phase, whether at home or in the office, through their consumption of electricity. This energy consumption is highly dependent on the specific user behaviour. A notebook is used for an average of four hours a day, consuming 32 watts of electricity, which results in a carbon footprint of 25 kg of $CO_2$ per year. It is assumed that a smartphone is usually plugged into a charger for four hours a day, consuming five watts during this time [36].

Of course, the production of digital devices such as smartphones, notebooks and televisions are also a major greenhouse gas emitter. These emissions are mainly caused by the process chemicals used in the extraction and processing of raw materials and the energy required for semiconductor production. For example, the production of a large flat-screen TV (over 50") emits 1000 kilograms of $CO_2$. For a laptop, 250 kilograms of $CO_2$ are emitted during production. It is estimated that a smartphone or a digital voice assistant (e.g. Alexa) emits about 100 kilograms of $CO_2$ during production [36].

## 4. Case studies

The SMEs we studied show a very different picture at the digital lifecycle level and at the level of digital maturity. As this article is not a case study, we present two extreme examples from Hungary, which differ greatly in both maturity and digital mindset.

The first example shows an insecticide and sanitary disinfection company from a digitalisation perspective. The company is located in an in-demand sector, but also has - apparently - not very high digital needs. In the first two initial years, it only used the legally required digitisation functions and the communication with its employees was done through digital consumerisation, using the employees' own smart devices. The mandatory functions are electronic invoicing, bookkeeping and tax reporting. Due to the nature of the sector, all of these were solved through cloud services. Their carbon footprint, which is not very high due to data traffic, can be considered negligible compared to similar SMEs in other sectors. As the company was targeting a larger market segment for development, digital development was necessary. The development required a "call centre" centre built on its own hardware assets. It also needed a dynamic web system through which information and orders could be managed. All of the latter were accessed via a cloud service, so electronic pollution was greatly increased. One positive consequence of this is that telephone communication has been greatly reduced - thus reducing the resulting electrical energy consumption and electromagnetic pollution. The possibility of operating the purchased hardware from its own device was also considered, but the cost of this was not covered by the SME (peopleware problem). Furthermore, a small business ERP on own hardware was implemented to manage stocks and orders. This had a relatively low power requirement to run - and seemed ideal from a cost perspective. The result of the company's improvements in this direction was an increase in turnover of about 10 times, an increase in energy consumption of only three times, and an overall increase in estimated emissions ($CO_2$ equivalent) of about four times. All this with the right choice of digitalisation.

The other company we studied is in the manufacturing sector, producing and selling oils. The company has ramped up its online activities during the coronavirus, with a dramatic surge in orders in the recent period. The website was developed by an external company even before the outbreak, in this case directly. Their website is responsive, i.e. optimised for different devices. Since January 2020, the use of social media has become even more conscious and intensive. A lot of effort is put into search engine optimisation. Around 60% of online purchases come from Google. Regarding the use of the cloud, everything is stored on servers, but advertising material is stored in the cloud. They use an administration system running on their own server to support their accounting, but they do not have the right software for production planning, so they can only do by own development. To eliminate this problem, the company is considering implementing a cloud-based ERP system, which is more advantageous from a budget and human resources point of view. It can be a crucial step in the life of the company as to which provider to purchase the system from. Because the company operates on a zero-waste approach, it is looking for a solution where the server park behind the cloud service is powered by renewable energy. Here again, the paradoxical idea of which solution has less impact on the environment comes into play. It should be stressed that, despite this, there is integration in the company, although it is not complete, but it is high for a company of this size. In terms of consumerisation of mobile telephony (a significant factor for SMEs), the performance is outstanding, as messaging applications are used extensively in everyday communication. This is a great solution in terms of process integration, as they are used to share up-to-date information on the different company activities. However, it also works on a cloud basis. This is counterbalanced by the fact that the company is powered by renewable energy, so the power supply for the company's own server and ICT devices can compensate for the use of the cloud.

Based on these results, it can be concluded that for the second company, there is no need for cloud asset optimisation, as sustainability considerations were already taken into account in the initial development. Although the introduction of hybrid solutions could be explored for growth and on-the-fly development, they would not really represent a reduction. It can be concluded that in the current situation, this business is operating in a near-optimal way from a digital perspective - in terms of emissions.

## 5. Solving and resolving the paradox

Digital sustainability requirements are the means by which digitalisation can achieve global sustainability goals [17]. However, it is not certain that the combination of digitalisation and sustainability will improve the performance of SMEs. There is a general view that the use of digitalisation as a toolbox will promote sustainability. However, it cannot be ignored that digitalisation can also be a disruptive force that, unintentionally, uncontrolled or underestimated, can negatively affect sustainability and its development.

Conversely, digital transformation of businesses can be achieved through sustainable development [21], in which case it is necessary to anticipate and minimise the risks and $CO_2$ emissions associated with digitalisation. Digital transformation brings a number of benefits, which also have a positive impact on combating climate change and reducing $CO_2$ emissions. However, ICT investment is an important component of $CO_2$ emissions. Indeed, the production, use and transfer of digital devices generate additional $CO_2$ emissions. This raises the question of whether the operation of a digitally mature SME will result in fewer $CO_2$ emissions.

It is very difficult to say whether, in the case of SMEs, increasing digital maturity and using better quality ICT tools will reduce or increase the emissions of the business, i.e., whether improving digital maturity (quality ICT use) to reduce emissions will increase the carbon footprint of the business. This paradox can be resolved for SMEs. Of course, it is important to look at the SME environment. The first important consideration is the economic sector or industry in which the SME operates. It makes a difference whether we are looking at a logistics transport company or an accountancy firm. Both have different ICT needs. For the former, accurate, real-time communication is very important and requires the use of state-of- the-art ICT tools. The first conclusion is that, depending on the sector, in each case an ICT environment should be provided that meets the needs but does not go beyond what is necessary and seeks to make targeted use of the tools. The number of redundant or redundant devices should be kept to a minimum, taking into account security concerns. ICT developments and tools should not be used as an end in themselves, unless the sector requires it, but only as a service. This will ensure that the project and the ICT environment do not lose out in terms of carbon footprint increase.

The conclusion is that the paradox can be resolved, and this can be considered a thesis. To resolve it, a component model must be constructed such that its constituent elements are as disjoint (independent in the case of a precise formulation) or as unconnected as possible in terms of carbon footprint. The components, i.e., to determine a uniform measure, shall be normalised and transformed to a uniform measurement scale. The relationships between the components must be defined so that no subcomponent is present in a larger proportion than is perceived in reality. After the relationships have been defined, a mapping must be defined that maps these relationships and transformed quantified values to a single standard carbon or eco- emission. With this, SMEs can now determine how their ICT development, their current level of ICT maturity, is having a detrimental impact on our environment and the future of our environment. They are thus able to determine an optimal level of emissions, which of course may be the opposite of the cost-oriented target function.

## 6. Conclusion

In our study, we have shown the impact that the conscious use of ICT can have on an SME, and how unjustified ICT development, the operation of unjustified high quality ICT devices with a lot of knowledge, can be detrimental to the carbon footprint. Despite their aim to reduce the carbon footprint, they have the opposite effect. To resolve this paradox, a model is needed that accurately shows SMEs their current emissions. As a result of digital development, the difference between the emissions of a new operation and the status quo can be modelled, allowing them to make sensible and smart decisions when making improvements.

Digital transformation brings many benefits that have a positive impact on the fight against climate change and the reduction of emissions. ICT investment is a major contributor to $CO_2$ emissions. The production, use, data transmission of digital devices, the power consumption of the internet network, the multiple data centres and servers/routers involved, the power consumption of the device during streaming all contribute to additional $CO_2$ emissions. In our study, we have shown the impact that ICT development in an SME can have on emissions and how unjustified ICT development, the acquisition and use of ICT devices with a lot of knowledge and of unjustified high quality, can be detrimental to the carbon footprint.

Having resolved the paradox, our primary objective will be to build the model, i.e., to create an objective function from the combination of cost and output. Once this has been done create, we will develop a tool that will use the model to map the exact ICT carbon footprint of the SME, helping it to make a digitisation decision. Then we want to get an empirical picture of the current $CO_2$ emissions of SMEs.

The digital paradox for SMEs states that, for an SME, digitalisation is an emission-reducing factor, while the consequence of digitisation can be higher harmful emissions. One of the new scientific results of this study is a detailed analysis of the paradox and the justification of the need for a model to resolve it, as there are currently no results in the literature. Mainstream research currently focuses on the carbon footprint, digitalisation and some of the links between SMEs, while studies published in the field of management and economics focus on digital development of financial systems, blockchain technology and digital development of customer-related processes. The other novel scientific result is the development of the basis for an optimisation model that, when adapted, will allow an SME to operate optimally economically while producing the least harmful emissions. In the present paper, we do not provide this model; we have only demonstrated that the development of such a model has an exact form and justification.

The main limitation is that the paper focused on literature research. On the other hand, currently it is difficult to measure the $CO_2$ emissions of ICT devices, that is why the paper does not include empirical tests.

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## Biographical notes

**Ágnes Sándor**
Ágnes Sándor is a research fellow at Budapest Business University Centre of Excellence for Future Value Chains. She got her PhD in 2022 in Management and Business Administration Science from the Budapest Business University. Her research interests focus on digitalisation, digital transformation of SME's, digital maturity and digital sustainability.

**Ákos Gubán**
Ákos Gubán was born in 1956. He got his master degree in mathematics at Science University of Szeged, Hungary in 1981. He got his PhD in 2004 in information science at the University of Miskolc, Hungary. His major field of research is AI, logistics and sustainability, information systems and sustainability and heuristic modelling. The State Insurance Company between 1989-90 employed him in the private between 1974 and 1990. Since 1990 he is employed by Budapest Business School, Collage of Finance and Accountancy, Department of Business Informatics as a full professor. He was also the head of department. Dr. Ákos Gubán is a member of Hungarian Association of Logistics, Purchasing and Inventory Management. Currently he is a Professor Emeritus.

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# The need for a risk management framework for data science projects: a systematic literature review

**Sucheta Lahiri**
School of Information Studies, Syracuse University
Syracuse city, New York State 13244
United States of America
sulahiri@syr.edu

**Jeff Saltz**
School of Information Studies, Syracuse University
Syracuse city, New York State 13244
United States of America
jsaltz@syr.edu

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**Sucheta Lahiri**
School of Information Studies, Syracuse University
Syracuse city, New York State 13244
United States of America
sulahiri@syr.edu

**Jeff Saltz**
School of Information Studies, Syracuse University
Syracuse city, New York State 13244
United States of America
jsaltz@syr.edu

**Abstract:**
Many data science endeavors encounter failure, surfacing at any project phase. Even after successful deployments, data science projects grapple with ethical dilemmas, such as bias and discrimination. Current project management methodologies prioritize efficiency and cost savings over risk management. The methodologies largely overlook the diverse risks of sociotechnical systems and risk articulation inherent in data science lifecycles. Conversely, while the established risk management framework (RMF) by NIST and McKinsey aims to manage AI risks, there is a heavy reliance on normative definitions of risk, neglecting the multifaceted subjectivities of data science project failures. This paper reports on a systematic literature review that identifies three main themes: Big Data Execution Issues, Demand for a Risk Management Framework tailored for Large-Scale Data Science Projects, and the need for a General Risk Management Framework for all Data Science Endeavors. Another overarching focus is on how risk is articulated by the institution and the practitioners. The paper discusses a novel and adaptive data science risk management framework – "DS EthiCo RMF" – which merges project management, ethics, and risk management for diverse data science projects into one holistic framework. This agile risk management framework DS EthiCo RMF can bridge the current divide between normative risk standards and the multitude of data science requirements, offering a human-centric method to navigate the intertwined sociotechnical risks of failure in data science projects.

**Keywords:**
project management; risk management framework; data science; bias; methodology.

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## 1. Introduction

Data science is an interdisciplinary field that employs statistical, machine learning, and artificial intelligence (AI) tools to determine insights from complex and situated data [1]. Another definition stems from the knowledge insights that data science methods draw from data [2]. The often-heterogeneous data is never 'raw' [5,8], and rather cooked. The data represents a combination of ideas, negotiated decisions, contexts, individuals, protocols, macroeconomic factors, and institutional practices [5]. Due to the nature of data science projects, the processes, and practices of organizing and analyzing data are however rarely linear and often more exploratory. Although data science work practices bringing together data, practitioners, and tools, are heterogeneous and involve discretionary human-led decisions; paradoxically there is still a dominant theme of technology deterministic information systems (IS) literature to explain data science projects [3,9]. In other words, there is scant sociotechnical research that explains the messiness, tension, power conflicts, and 'how' the data science work is performed to create systems [4,5]. The case study of Google Maps and the politics of cartography provided in the second section of this paper is one such example of human biases and political influence in the making of the system. The cartography also testifies that the making is not objective and rather involves the discretion of various stakeholders who hold vested power.

Also, the research on data science work is studied mostly in the realm of restricted academic settings and not in real-time or practical corporate settings where the systems are deployed and distributed by data science practitioners [5]. The practitioners who are engaged in the making are driven by organizational goals, perceived incentives, institutional policies, and established processes. It is important here to recognize the collaborative human work of data science practitioners that is often invisible but essential in developing sociotechnical systems. In other words, data science as a sociotechnical system involves a great deal of human labor that collaboratively aids in data processing and analysis [6]. Methodological choices and contextual factors further affect the process of data analysis and consequently decision-making. In critical data studies, scholars characterize data science projects as messy and sociomaterial endeavors in which practitioners and technical skills together culminate sense-making and discretionary decision-making with data [5,7].

The collaborative work of data science in project execution raises several questions about data and system creation, such as how the data is produced, who is involved in data processing, what processes are used for managing data science projects, how is data managed and analyzed, how are business objectives translated into system development, how are knowledge insights interpreted, and who ultimately approves or rejects the final system. Additionally, questions about coercion, persuasion, and the legitimized and de-legitimized voices are important considerations in this process. Finally, understanding how a system is deemed a failure is crucial for improving the data science processes.

In a data-driven culture that values data practices, there are numerous areas of concern surrounding the process of creating data science knowledge insights. Specifically, questions linger around how a data science project's entire workflow is carried out and the risks of project failure emerge during the system creation process [10].

In this paper, we begin by understanding how failure is defined for data science projects, and why it is important to rather understand the risks before the failure of data science projects. We then define various types of risks of failure for data science projects with examples. Following the need to explore risk mitigation with risk management framework (RMF) for data science projects, we dedicate the next section to explain the methodology to conduct an in-depth SLR on RMF for data science projects. The last sections highlight the findings of the SLR and the proposal for an agile risk management framework DS EthiCo RMF to manage the risks of failure for data science projects.

The concept of failure has been defined in IS literature using the "iron triangle" of time, cost, and quality [11,12]. More broadly, project failure can occur when business objectives, processes, interactions, or user expectations are not met in the proposed timelines. However, failure is not a universal concept - its meaning and implications depend on the specific context. In other words, failure cannot follow a 'one size fits all' approach. For data science projects, one common definition is a failure to deploy the project into production, with studies showing up to 87% of projects end up before deployment [13,16,43]. However, this narrow view misses other important failure modes, such as successfully launched systems that break down in distribution or cause harm in practice [14]. Data science initiatives can also fail by producing unreliable predictions that undermine stakeholder trust or propagating biased results despite passing the testing phase. In essence, deployed models can fail by perpetuating human biases. Defining failure requires looking beyond the project deployment and before failure, the risk of failure to consider potential societal damages from biased, inaccurate, or unusable data science systems after the final launch.

While extensive research exists on utilizing data science for risk management, such as stochastic models driven by Bayesian Statistics to assess the systemic risk of the financial market [15], less attention is paid to managing the risks introduced by data science itself [10]. Despite the literature on the risks of software development projects, the research on data science risk is sparse [10,14,44]. This lack of research on managing data science project risk was determined via the results of an SLR that explored the use of RMF for managing data science project risk [10]. The SLR explored if there was any dedicated RMF for addressing the risk introduced when organizations use data science projects. The SLR explored published relevant conference papers, proceedings, and peer-reviewed journal papers from 2015 to 2019. The content analysis with title, abstract, and subsequent full-text analysis of filtered articles derived from generic or very specific standards that are not dedicated to data science was proposed to manage data science risk. In other words, no articles were found that explicitly highlighted RMF for data science projects. This study also highlighted that ethics was seen as a weak theme for RMF compared to other dominant themes such as big data execution challenges and sector-specific RMFs.

Due to the lack of research literature on the risks of data science while project execution deduced through the SLR conducted in 2019, this paper extends the SLR in 2022 to understand the trend of research done in data science risk of failure. The research probes the following overarching question:

**RQ:** How does the trend of literature on risks of data science failure show evidence of risk management frameworks?

The paper is divided into five sections. The first section provides a brief introduction to data science failure and associated research. The second section outlines various types of data science project failures. The third section describes both general and AI-specific RMFs that are recommended to be used for data science projects. This is followed by the fourth section describing the methodology for SLR to explore the risks of data science projects. The fifth section explains the results of a new SLR. Finally, the discussion section highlights the synopsis of existing RMFs for AI projects, followed by potential next steps and a summary section on agile-based risk management framework DS EthiCo RMF for managing the diverse risks of failure for data science projects.

## 2. Data science projects failures

Data science projects are unique from other IT projects such as software development due to their higher complexity [4], with a greater emphasis on data compared to typical software projects. In other words, data science projects possess certain characteristics that elevate the risk of failure when compared to IT projects [4].

Data science projects involve a greater magnitude of structured and unstructured data, requiring due diligence to ensure data homogeneity and an emphasis on data lineage. Data science projects often have uncertain inputs and outputs due to unspecified objectives and project complexity, with the scope of these projects having expanded from descriptive to predictive and prescriptive with the introduction of AI tools [4]. The practitioners involved in data science projects aim not only to meet business objectives but also to investigate the extent to which knowledge insights add value to business decisions, emphasizing the multiple dimensions of failures relating to the complexity and scope of these projects.

Empirical studies on data science project failure highlight project challenges as data issues with access, quality and volume, budget, security, unstructured project execution, change management, unrealistic expectations, use case-related issues, talent, constraining regulations, lack of documentation, lack of transparency, scope creep, cyber-attacks, poor stakeholder management [17,18,19]. In other words, the failure of data science projects is linked to technological failure or regulatory breaches, as well as to potential societal harm through the misuse of AI.

### *2.1 Types of data science project failures*

The Project Management Institute (PMI) defines a project as a “temporary effort to create a unique product, service or result” [20]. However, this definition does not fully capture the complexity of data science initiatives. While data science projects begin with a defined business objective and scope, these components often shift over time. Compared to IT projects, data science requires greater attention to detail, especially in data preparation. Unfortunately, failure rates are higher for data science than IT, stemming from three key challenge areas [21]:

- Data challenges arise from properties like variety, quality, availability, and volume across structured, unstructured, and social media sources.
- Process challenges relate to eliciting requirements, capturing/processing data, analysis, modeling, interpreting outputs, and more.
- Management challenges cover governance, privacy, ethics, regulations, policies, and infrastructure.

While process and management challenges affect any project, data issues are unique to data science. In particular, introducing bias through predictive models is a central data science risk of failure. Other drivers of failure include a lack of expertise and an inability to adapt to unexpected events. In summary, the mutable objectives, intensive data needs, and advanced data science techniques led to higher failure rates than traditional IT initiatives.

### *2.2 Risk of failure: types of data science project failure risk*

Risk encompasses various hazards like social, climate, financial, legal, and reputational threats. Risk is commonly defined as a potential, anticipated danger before failure. Quantitatively, it represents the probability of an event and its positive or negative consequences. However, focusing only on the magnitude of risk fails to capture the full harm an event may inflict on society. Additionally, the subjectivity in determining disruptive algorithmic risks makes complete quantification elusive.

Existing project risk definitions, like that from the UK Association for Project Management, describe risk as uncertain circumstances that can impact objectives [22]. Per the Project Management Body of Knowledge (PMBoK), risks are uncertain events that, if occurring, sway objectives positively or negatively [23]. The PMBoK delineates known and unknown risks – those that are legitimized are managed while others stay opaque or left unidentified. Critically examining which data science risks are articulated versus overlooked, and developing techniques to manage failure risks, are vital as not all risks can be fully predicted or mathematically expressed. For instance, a notable example is Microsoft’s Tay chatbot, which encountered issues with hate speech due to the presence of unfiltered public data. Despite data science professionals clearing the Tay bot project for user distribution, the overlooked risks associated with incorporating contaminated data had detrimental consequences [24]. Similarly, voice recognition models may encounter challenges in identifying higher-pitched voices, potentially perpetuating stereotypical gender biases towards more feminine voices. These risks can emerge even after rigorous evaluation checks, highlighting the complexity of ensuring a completely risk-free model.

Another example of risks of data science failure through cartographic politics is visible through Google Maps, which provides two different geospatial visualizations of contested areas between India and Pakistan in two locations [25]. The political incompatibility of over 70 years has given rise to a social construction of maps represented through Google Maps. For instance, Figure 1 shows the map available to citizens of Pakistan and the rest of the world and indicates areas of dispute through grey dotted lines.

On the other hand, the Google map in Figure 2 below is made available to the citizens of the Indian subcontinent. Unlike the map created for Pakistani and global citizens, India’s map is different with the dotted lines of disputes missing. On the contrary, solid borders are shown to indicate that the disputed area is under the control of Indian territory.


Fig. 1. From Pakistan's view, Kashmir looks disputed. The dotted lines show the areas of dispute.

*Source: G. Bensinger, “Google redraws the borders on maps depending on who’s looking,” Washington Post, 2020.


Fig. 2. From India, the entire region of Jammu and Kashmir looks like a part of India

*Source: G. Bensinger, “Google redraws the borders on maps depending on who’s looking,” Washington Post, 2020.

The slogan of Google is “to organize the world’s information”. Essentially, Google asserts that it relies on data sources that best depict borders as outlined in treaties and from highly revered entities such as the UN and ISO [25]. However, in this example, one can see that the mission bends to their discretion, or that they present “alternative facts” based on the content of the request.

As can be deciphered from the above-cited example, risk can be construed as a social and political concept. The factors used to classify events as risk-prone or not are negotiated by individuals and risk policy systems.

The mathematical definition of risk in the social world is not always accepted and rather criticized for several reasons. The mathematical representation of risk does not consider multiple definitions of risk either. The complex, multi-layered expected consequences defined with the mathematical definition cannot fully capture the average probabilities used in technical risk analyses. Limiting the scope of risk with a magnitude can increase the scope of actual risk. Additionally, defining risk as a single numerical quantity does not provide a broader picture of how harm is affected across individuals [26].

In the context of data science, one of the limitations is the difficulty in quantifying the uncertainty of risk while a project is ongoing. One example of the likelihood of a risk event is the usage of incomplete or irrelevant data for machine learning projects. The risk of uncertainty can be classified into two categories: uncertainties inherent to data that cannot be eliminated, and epistemic uncertainties arising when there is a lack of knowledge [27]. Furthermore, it is essential to recognize that these risks may not always occur in isolation but can be interconnected, creating a web of potential vulnerabilities that further complicate the project's health. Therefore, careful consideration and ongoing vigilance are crucial to mitigate risks throughout the entire life cycle of data science initiatives.

Many factors can lead to the failure of data science projects. A primary reason is the absence of a structured process model or methodology [14]. This indicates that the root of data science project failure is frequently not technical but rather tied to inadequate or misaligned project management approaches. Despite the existence of knowledge discovery in databases (KDD) as one of the methods for generating knowledge from vast amounts of data, the project management methodologies developed and motivated by KDD have not undergone any substantial material changes [4]. For example, one of the most extensively used project management methodologies is Cross Industry Standard Process for Data Mining (CRISP-DM) developed in the 1990s with funding from the EU. CRISP-DM was defined for managing data mining projects, and it became the most popular methodology for managing data science projects. CRISP-DM consists of five high-level steps: business understanding, data understanding, data preparation, modeling, evaluation, and deployment.

A paradoxical approach to data science project failure is observed with an iterative agile methodology where the data science practitioners are encouraged to drive projects to failure early so that they can learn from the failure and rectify it to avoid major material damage. The team is encouraged to "fail fast to learn fast", which indicates that it is acceptable for an iteration to fail when a project uses an agile approach and breaks the work into smaller iterations [29]. This type of failure is encouraged to be realized and in turn, helps to better inform the practitioners how to execute the rest of the project without any further failures with more severe consequences. Failing fast enables the identification of solutions that show promise versus those that have the propensity to break down. Using an iterative agile process, the failures realized during an iteration are accepted as a means to prepare for a better output in the next phase. These failures are anticipated, and data scientists are prepared to accept the disappointment of that result. On the other hand, project failure is not anticipated and can occur at any phase of the project workflow, even after the approved artifact is distributed. Although CRISP-DM is not an agile process framework, this concept of acceptable iteration failure demonstrates the many types of project failures.

## 3. Potential risk management frameworks for data science projects

### *3.1 General purpose risk management framework*

There are different international standards for risk management adopted and applied by organizations to introduce their own internal rules and guidelines. These standards also operationalize risk and solicit guidelines or general steps of mitigation. Unlike methodologies, standards do not provide a workflow to manage projects. While there are many risk management frameworks, such as ISO and COBIT [30], following are two of the more popular international risk management frameworks used by private and public organizations.

#### 3.1.1 COSO (Committee of Sponsoring Organizations)

In 1985, the Committee of Sponsoring Organizations (COSO) was established through the collaborative efforts of leading institutions, including the American Accounting Association, American Institute of CPAs, Financial Executives International, Institute of Management Accountants, and Institute of Internal Auditors [31]. COSO backed the National Commission on Fraudulent Financial Reporting, an autonomous private-sector initiative aimed at identifying factors leading to deceptive financial reporting.

COSO's primary mission encompasses thought leadership in three core areas: (1) enterprise risk management, (2) internal control, and (3) fraud deterrence. In 2017, COSO introduced an exhaustive ERM framework titled "Enterprise Risk Management - Integrating with Strategy and Performance." This framework emphasizes consolidating isolated risks into a unified enterprise architecture. ERM is also characterized as "a process undertaken by an organization's leadership, management, and other stakeholders, designed during strategy formulation and execution, to identify potential events affecting the organization, and manage risks within its tolerance, ensuring reasonable assurance in achieving organizational objectives" [32]. COSO's ERM approach is top-down, spearheaded by management, with risk-focused deliberations occurring at strategic echelons, such as capital allocation discussions. A hallmark of the 2017 framework is its emphasis on corporate governance, organizational culture, and strategy formulation.

#### 3.1.2 Three lines of defense (LoD)

The Institute of Internal Auditors (IIA) introduced the Three Lines of Defense (LoD) model in response to the financial crisis, aiming for a more structured and unified approach to risk management [32]. This model delineates the organization's roles in managing risk across strategic, tactical, and operational tiers. The "3LoD" risk management model clarifies reporting obligations, metrics, and risk mitigation as follows:

- 1st Line of Defense: Encompasses both financial and non-financial activities that generate risk.
- 2nd Line of Defense: Covers roles responsible for risk oversight that aid in deploying the RMF. This tier also stipulates risk appetite, control measures, and independently supervises the risk management actions of the first line.
- 3rd Line of Defense: Comprises the group audit, ensuring the establishment and maintenance of internal control systems and risk management procedures.

While global standards like COSO serve as foundational frameworks that some companies leverage to construct data science risk management strategies, these standards often overlook specific risks inherent to data science projects [30]. In essence, while these standards provide a foundational scaffold upon which organizations - both private and public - can shape their risk appetite and thresholds, they fall short in addressing distinct risks pivotal to data science projects, which are central culprits of their failures. Nevertheless, a few RMFs have emerged that focus on addressing these data science-centric project risks.

### 3.2 Data science-specific risk management framework

While the previous SLR conducted in 2019 [10] did not find data science-specific risk management frameworks discussed or evaluated, there are several recent frameworks defined by organizations in the industry dedicated to model risk and AI. Although risks generated from forecasting models and AI might be different than the phenomenon of data science, we treat these concepts under the umbrella of data science.

#### 3.2.1 Model risk management

Model risk management (MRM) has been employed to oversee and track AI model risks, especially within sectors such as financial services. MRM focuses on the management of risks stemming from potential negative outcomes due to decisions informed by flawed or inappropriately used models. The primary goal of MRM is to detect, quantify, and address risks associated with model inaccuracies or inappropriate application.

Nonetheless, recent observations suggest that traditional MRM approaches are becoming less effective due to the following reasons [33]:

- Evaluations under MRM are typically conducted once every one to five years, yet AI models frequently adapt based on ever-changing data. In the intervals between assessments, while MRM presumes model constancy, these models are, in reality, dynamic, evolving with data shifts.
- The review process of MRM can span 6 to 12 weeks post-model development, leading to deployment delays. The linear process of MRM does not seamlessly integrate with agile methodologies.
- MRM traditionally focuses on conventional risks, such as credit risk or capital sufficiency. However, modern challenges like reputational risk, consumer risk, employee-related risk, conduct risk, and biases often remain unaddressed.
- AI solutions are not homogenous. The landscape encompasses varied systems, from chatbots to HR analytics tools. These cutting-edge models differ fundamentally from traditional AI frameworks, like stress-testing or credit-risk models.

### *3.2.2 NIST artificial intelligence risk management framework 1.0*

On January 26th, 2023, in collaboration with various public and private entities, NIST introduced the sector-neutral Artificial Intelligence Risk Management Framework (AI RMF 1.0) along with supplementary materials [34]. This Framework proposed as an elective tool, aims to assist organizations in effectively addressing societal risks posed by artificial intelligence. Moreover, it serves as a preventive measure against risks faced by both individuals and institutions. In other words, given the vast applicability of AI, the Framework extends its reach not just to organizations but also encompasses individual, communal, and societal dimensions. The AI RMF is crafted to bolster credibility and encourage the creation of ethically sound AI systems for both the public and private sectors. Formulated in compliance with the National AI Initiative Act of 2020, recommendations from the National Security Commission on Artificial Intelligence, and the Plan for Federal Engagement in AI Standards and Related Tools, the AI RMF is a consensual structure rooted in collaboration. NIST's AI Framework characterizes risk as the likelihood and ramifications of adverse outcomes. Echoing ISO 31000:2018's risk definition, it seeks not only to curtail AI-associated hazards but also to harness potential beneficial outcomes in harmony with societal well-being. It pinpoints three primary risk categories targeting (1) individuals, (2) institutions, and (3) broader ecosystems. These risks range from societal and reputational dangers to environmental threats. The NIST RMF advocates for a comprehensive test, evaluation, verification, and validation (TEVV) approach throughout an artifact's lifecycle. While the Framework outlines broad risk management principles centered on the collaborative efforts of societal stakeholders, it lacks detailed guidance on navigating various model lifecycle stages - from conceptualization and data handling to deployment and impact assessment. Similarly, while it lists essential AI model attributes like trustworthiness, validity, and transparency, referencing ISO definitions, these descriptions are prescriptive without providing concrete steps to realize an optimal AI system. Future iterations of the NIST RMF plan to incorporate evaluations to gauge its efficacy in enhancing AI risk management [35].

Overall, there are four core functions of AI RMF: **governing** a culture of risk management which sets the control, depending upon the content the risk elements are **mapped**, **measuring,** or assessing the risk after identifying, and finally risks are prioritized and **managed**. The functions are described as high-level activities. Although the functions are claimed as actions with specific outputs, the guidelines are merely considered as checklists that require further research on deployment. For example, the playbook along with the guide to NIST AI RMF fosters the culture of risk management. However, it is not necessary that organizations operate with formal risk management business lines to manage risk. The risk management pillar can be embedded in an umbrella business line without explicitly working as a core function. It is necessary to then describe how the culture of risk management is defined on an organizational level where risk management practices are considered taken for granted. Additionally, social actors might have their intrinsic values or perceptions of defining risk. It is necessary to understand that in many organizations, documentation may not be created or in use for being labor intensive. A proxy measure should be advised where the suggested actions do not apply to the playbook. Another issue of transitioning to NIST AI RMF from the existing RMF or risk management process is not explained. In other words, change management remains an issue.

There are organizations where ad-hoc risk management processes are deployed. This poses the question if NIST AI RMF will apply to immature risk management processes. Also, as the implementation of the Framework lies at the discretion of mature processes, there are guidelines to follow and practices to adhere to, while working on AI projects. The intervention of guidelines and protocols with RMF might question the institutional aversion to acknowledge or bypass the protocol. For example, too many and too stringent guidelines if assigned to the practitioners, might be perceived as a roadblock to the AI innovation initiatives of the institutions. For example, according to Deloitte, the NIST AI risk management framework for artificial intelligence is recommended for identifying and managing the risk 'without hindering innovation with overly restrictive controls' [36]. In other words, the organization does not want to follow the framework at the cost of losing the opportunities that lead to AI innovation.

The categories and subcategories of the Framework call for human-led capabilities, processes, and procedures for deployment. It is still unclear if this Framework is only inclusive for the corporations that cannot afford resources and social actors for successful deployment. Clear guidelines around what constitutes 'third party' software are not defined which makes it difficult to ascertain if there should be a contingency procedure for third-party risk.

Amidst COVID-19, there are many changes around staff lay-offs, changes in the behavior of consumers, budget cuts, and data no longer in use for the model as the user sentiments have changed [37]. There is an ambiguity if the Framework can take the hit of climate risk.

Overall, the Framework is a steppingstone for the thinking process around risk management for artificial intelligence. However, it does not look at data science as a phenomenon that encompasses many more risks and contextual complexities around risk mitigation.

### *3.2.3 AI risk management framework by McKinsey*

In the evolving landscape of AI, McKinsey emphasizes the integration of risk management within the AI innovation process to ensure continuous monitoring and adaptation in line with the fluid nature of data-driven cultures. In essence, the RMF should possess the ability to evolve. A salient challenge with a static framework is the protracted model risk management workflows, often spanning six to 12 weeks post-deployment for review. Such delays could lead to emergent use cases, necessitating another round of MRM workflow. Considering the multifaceted risks—encompassing model, operational, privacy, and reputational dimensions—it becomes intricate for stakeholders to efficiently oversee and coordinate risk. This scenario spurs a pivotal question: should risk management be centralized or decentralized?

To navigate these multifarious risk scenarios, McKinsey introduces an agile-centric risk management approach termed "derisking AI by design" [38]. This approach can be distilled into three primary stages: (1) endorsement for ideation, encompassing PoC/MVP/development; (2) green light for implementation, including data acquisition, evaluation, and model construction; and (3) authorization for deployment, covering inventory evaluation, monitoring, and review.

"AI by design" advocates for early integration of risk management measures during model formulation. By concurrently aligning risk management with model development, practitioners can circumvent prolonged waits post-model creation. Additionally, concurrent checkpoints for risk identification, evaluation, and control checks can yield efficiencies in terms of time, resources, and cost. This integrative approach, embedding controls within the development trajectory, proves especially advantageous for entities boasting advanced risk analytics divisions. Such a setup empowers risk management professionals to confidently embrace agile methodologies, facilitating swifter independent reviews.

To embark on this journey, irrespective of an organization's risk management maturity, senior leaders should undertake the following steps to centrally coordinate the "derisking AI by design" approach:

- Ethical Guideline Assimilation: Leadership should adopt a top-down perspective, critically appraising AI's ethical contours, recognizing guidelines, and understanding potential risks.
- Conceptual Framework Design: Based on established principles, an AI risk management framework should be crafted, encompassing stages from ideation to model review. Establish Governance & Define Roles: Subsequent steps involve identifying suitable professionals for analytics and risk management, ensuring their roles vis-à-vis

AI risk controls are lucidly articulated. Comprehensive training sessions should be organized to facilitate foundational analytics knowledge.
- Embrace Agile Risk Management: Analytics and risk management teams should collaborate, leveraging agile and sprint methodologies, fostering interdependence and efficient conflict resolution.
- Champion Transparency & Explainability: Cultivating a culture prioritizing tools with transparency and explainability features is paramount.
- Promote Awareness: Host awareness campaigns and workshops to familiarize risk and compliance professionals with intricate, risk-laden use cases.

It is pivotal to note that this framework predominantly adopts a technology-centric stance, overshadowing a more comprehensive sociotechnical perspective. Moreover, its design predominantly targets individual models, rather than the broader ambit of data science.

## 4. SLR for risk management framework for data science projects

### *4.1 SLR Methodology*

Content analysis can be defined as “a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use” [28,30]. The content analysis for this SLR begins with the first step by identifying the research question. The overarching research question as mentioned in section two above is driven by the research questions of SLR in 2019, and the derived findings. The second step is to locate the appropriate data that can answer the research question. The scope of the data used for this SLR is restricted to six repositories – ACM Digital Library, IEEE Explore, Google Scholar, Science Direct, Scopus, and Web of Science. The third step is the random sampling of picking up the text articles based on keywords, titles, abstracts, and summaries that can represent the focused corpus of text on data science risk. The articles are picked up basis the relevance and the search are conducted till the articles are repetitive or irrelevant. The fourth step is to validate and reconcile the identified articles between the primary and secondary authors. The fifth step is to deep dive into the full text of the articles to check the relevance and derive themes. The sixth step is to validate, reconcile, and create a tree structure of the themes derived by both authors. In other words, broader themes are identified, and as a basis for the relationship between the two, a meaningful hierarchy of themes is clustered together. Finally, the frequency distribution of the themes is calculated to create a bar diagram of weaker and stronger themes.

To understand the current research and usage of risk management frameworks when organizations execute data science projects, a systematic literature review was conducted. This SLR was an extension of the SLR conducted in 2020 that focused on exploring the presence of a risk management framework for data science projects [10].

There were seven keyword search themes identified in the previous systematic literature search conducted in 2020 [30]. These same themes and the keyword combinations were taken as a starting point for this updated SLR (Figure 3).

The SLR started with a search of pertinent articles with six repositories – ACM Digital Library, IEEE Explore, Google Scholar, Science Direct, Scopus, and Web of Science. In terms of the search criteria, we restricted the period between 2021 and 2022 till October. Only English-language peer-reviewed conference proceedings, journal articles, and conference papers were added to the search results. The book chapters, theses, and inaccessible articles were discarded. In other words, the search criteria leveraged what was used for the 2019 SLR, except for the time bracket.

Specifically, to source relevant articles for the SLR, all keywords used in the initial SLR in 2019 were used, with one exception: the theme of “What is Big Data/Data Analytics/AI?” This exclusion stemmed from the theme’s emphasis on defining and elucidating the characteristics of big data, data analytics, and artificial intelligence, rather than addressing risk management frameworks for data science projects. A new keyword focusing on machine learning was added owing to the increasing use of that term on titles observed during article searches.

Once the articles were identified, the first step was to identify duplicates (the same article was found multiple times). Then, each paper was reviewed with title, abstract, and conclusion in detail by two reviewers, to determine if the paper should be included in the analysis. Next, via detailed content analysis, done independently by two researchers, each article was designated with a topic. After brainstorming the topics, the mismatch of topics was reconciled. New themes were derived. Throughout the process, regular discussions between the two researchers focused on differences in analysis. In other words, there were active brainstorming meetings to discuss mismatches of topics, which were then reconciled, to map the mutually agreed topics and themes.

Hence, the new literature review was both inductive and deductive. The SLR followed a deductive approach by analyzing if the patterns of the themes that had been uncovered in the previous SLR remained the same. In addition, the analysis adopted an inductive approach, as the authors remained open to identifying new themes without being confined to pre-existing ones found in the previous SLR.

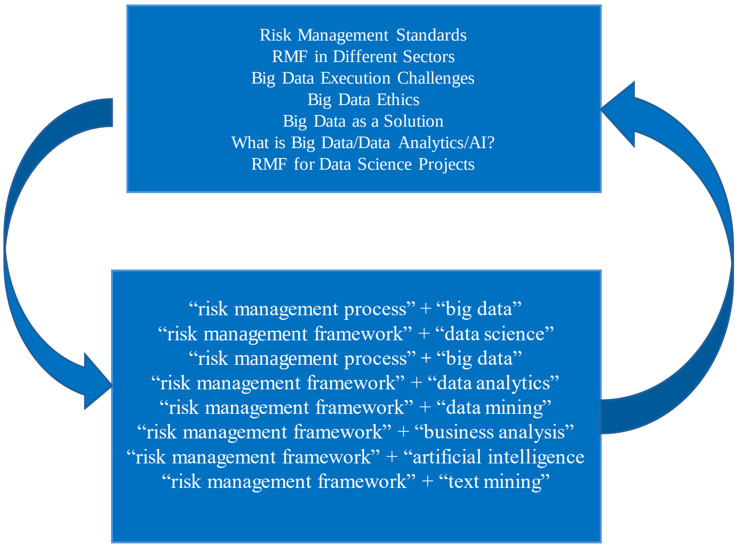


Fig.3. Themes and Keyword Combinations used for SLR

## 5. Results and Discussion

### *5.1 SLR results*

There was initially a total of 74 relevant articles identified for this SLR after scanning the title, abstract, keywords, and summary and weeding out duplicate items. The following frequency distribution of the articles was gleaned as per the figure 4. The keyword “Big Data” had the maximum frequency of appearance with the keyword strings risk management framework and risk management process. Out of 74 relevant articles, there were 34 unique articles identified after reconciliation with the secondary author. The 34 articles were then reviewed in depth with full-text analysis, which reduced the total number of articles to 14. All articles were then explored via content analysis, with the following dominant themes identified: *exploring AI Risks, governance for AI, RMF for AI, RMF for using AI, and RMF for Implementing AI in banking*.

As shown in Table 1, the *Need for an RMF specifically for the Big Data Science Projects* theme had the maximum frequency. This theme consisted of all the articles that stated the need for a risk management framework to minimize data science-specific risks (ex. bias, transparency, algorithm fairness). This observation highlighted growing research in risk management for data science projects. Specifically, two out of six published articles advocated for more research in risk management for data science projects. One of the other four articles highlighted the need to have risk-cognizant machine learning systems.

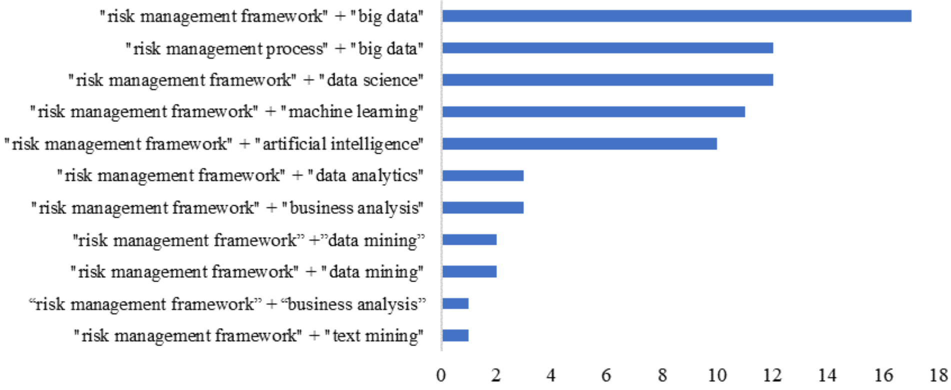


Fig. 4. Frequency Distribution of Keyword Combinations used in SLR

Table 1. Final themes gathered after full-text analysis of 34 unique articles

| **Keyword strings** | **Number of articles obtained with SLR** | **Themes gathered** |
|---|---|---|
| "risk management framework" + "big data"<br>"risk management process" + "big data"<br>"risk management framework" + "big data" | 4 | Big Data Execution Challenges |
| "risk management framework" + "machine learning"<br>"risk management framework" + "data science"<br>"risk management framework" + "big data"<br>"risk management framework" + "data analytics"<br>"risk management framework" + "data science" | 6 | Need for an RMF specifically for Big Data Science Projects |
| "risk management framework" + "machine learning"<br>"risk management framework" + "artificial intelligence"<br>"risk management process"" + "big data" | 4 | RMF for specifically for Big Data Science Projects |

Overall, the theme *Need for an RMF specifically for Big Data Science Projects* in Figure 5 stood out to encourage more research on finding solutions to managing risks for data science projects.

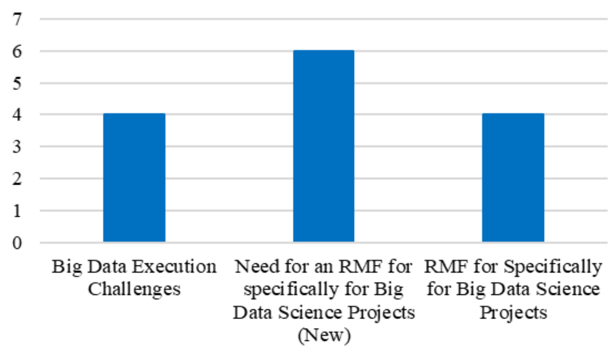


Fig. 5. 14 Articles Gleaned Through SLR in 2022

### *5.2 Key Insights*

While established frameworks like Scrum and CRISP-DM offer methodologies to oversee data science projects, neither explicitly emphasizes risk management. Contemporary literature remains conspicuously silent on addressing specific data science risks through these project management methodologies. Aho et al. [39] noted this gap, and a systematic literature review (SLR) by [30] found a stark absence of standardized risk management frameworks catering to the distinct risks of data science projects.

NIST Risk management framework for AI and McKinsey's AI by design is aligned with AI and models respectively without looking at data science as a phenomenon. NIST AI RMF is a generic list of risk management control measures whereas Mckinsey's AI by design is more use-case specific.

On the other hand, existing risk management frameworks such as COSO do not explicitly integrate with current data science process frameworks. However, as noted by NIST [40, p23], the best RMF implementation is indistinguishable from the routine system development lifecycle processes carried out by organizations. That is, RMF tasks are closely aligned with the ongoing activities in the system development lifecycle processes. Hence, for risk management to be fully integrated into the team's process, the risk management framework must be explicitly integrated with the data science team's process.

Based on the clear potential risk of model bias in building predictive models, one question that arises is, what is the appropriate data science process used by the data science team while developing the artifact, and does that process reduce the risk of bias and fairness and more generally, the potential of harming certain groups or segments of the population?

This process needs to consider that, in the social world, the contemplation of risk emphasizes the mental models of different groups of people who interpret harm and hazard through their worldviews. If the risk reflects the standards set by a specific group of experts (e.g., white male data scientists), then this group might miss project risks that others might more easily identify and mitigate. In other words, due to the multiple views of risk management, different people, different organizations, and different cultures might try to identify and manage risk via different approaches.

In the context of project management for data science projects, the field needs to investigate how risk can occur, who might be responsible for mitigating that risk, how hazardous that risk might be, who might be impacted, and when the risk might be ignored (for example, due to minimal customer impact or compromising ethical risk in place of profits). Hence, research is needed to explore the viability of a risk management framework for data science to address project risks and ethical hazards when teams execute data science projects.

### *5.3 Potential next steps*

Millstone et al. [41] defined three models of governance structure that can be considered for developing project risk management framework for data science projects:

- 'Technocratic' model in which scientists directly inform objectives through policy making. Scientists are the decision-makers who inform the policymakers on what to do.
- The 'Decisionistic' model follows the Red Book model in which the scientific aspects through risk assessment marry the political and value aspects through risk management through the overall process of risk analysis.
- 'Transparent (inclusive) governance' model in which actors from science, politics, economics, and science are invited to make contributions to risk assessment and risk management [42].

A data science project risk management framework should leverage this approach, as it will help identify and mitigate the full range of biases previously discussed. Having said that, due diligence must be done to make sure that not just scientists, but social scientists are involved in deciphering and borrowing the policymaking for risk management framework.

To start, one could explore everyday data science work practices, processes, existing measures of risk mitigation, and gold standards deployed in data science projects to manage risk. Furthermore, one could explore both the formal and informal work of data scientists that would help me locate vulnerable areas of risk and plausible solutions. One could also look at how data scientists participate in visible and taken-for-granted work to manage risk embedded in the day-to-day lives at the workplace. The goal would be to explore specific activities that are aligned with minimizing risk.

Future research could leverage specific milestones or structured approaches with incremental stages to explore a data science project risk management framework that carries not only the objectives of science but also the subjectivities of sensory experiences of civil society. Some other potential next steps are to create surveys to explore the thoughts of data scientists on project risk management frameworks for data science projects and to conduct ethnography studies to get more detailed insights.

### *5.4 Limitations*

One of the limitations of the SLR was the usage of restricted keyword strings for deriving the search results. The extended SLR in 2022 was based on the keyword strings used in the earlier SLR study conducted in 2020. A broader scope of keyword search strings might have disclosed a wider scope for articles and diverse themes. Another limitation was the selection of time for considering the literature for the SLR. The SLR is from 2019 till 2022 which does not include the focused literature for 2023. The SLR also had a restricted set of sources to search for articles, this circumvented the study to only six repositories – ACM Digital Library, IEEE Explore, Google Scholar, Science Direct, Scopus, and Web of Science. As data science is a phenomenon that encapsulates machine learning, artificial intelligence, data and business analytics, and text mining, there is also a likely debate on how inclusive the risk management framework should be, which this SLR does not cover.

## 6. Conclusion

In essence, while data scientists should proactively consider risk management strategies for successful project outcomes, there remains an evident gap in frameworks that facilitate teams in identifying and addressing these risks. Consequently, focused exploration into project management methodologies tailored to pinpoint risk elements specific to data science projects is warranted. This imperative distinguishes itself from the emphasis in Saltz’s 2015 study [4], which highlighted the necessity for well-defined data science processes and roles. Saltz’s study addressed the prevailing trial-and-error or ad-hoc approaches adopted by practitioners and delved into recurrent challenges like data quality and source uncertainties. The current emphasis pivots towards addressing latent vulnerabilities in data science practices, which may inadvertently introduce unmanaged risks. The envisioned risk management structure constitutes a governance model specifically tailored for data science projects, encompassing comprehensive risk assessment, management, and communication.

The broader objective for the domain should be to analyze the multifaceted and global character of data science endeavors steered by process methodologies. The end goal is to empower teams to judiciously evaluate data science-associated risks and pitfalls, culminating in the formulation of an adaptive Data Science Ethical Collaborative Project Risk Management Framework (DS EthiCo RMF). DS EthiCo RMF is an agile-driven enterprise-level risk management framework that manages the risks of data science on a project level. As the project can be executed by multiple stakeholders, there also lies the possibility of the practitioners being co-located or sparsely distributed across multiple locations. Also, the requirements of the external stakeholders or clients are subject to change for data science projects, DS EthiCo RMF is agile driven to bring effective communication and flexibility. This framework, catering to a diverse and global audience, marries traditional project management methodologies with an ethical risk paradigm. The ethical dimension of this framework mandates active collaboration among data scientists, project managers, social scientists, and a varied user base. Summarily, the pivotal research inquiry to be addressed is:

How can we devise an adaptive risk management framework that seamlessly integrates ethical principles and project methodologies, tailored explicitly for geographically dispersed data science initiatives?

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**Biographical notes**

**Sucheta Lahiri**
Sucheta Lahiri is a fifth-year PhD candidate at the School of Information Studies at Syracuse University. Her research focuses on understanding the risks faced by Global South data science practitioners during the execution of projects. Lahiri's work aims to shed light on how specific social agents legitimize and de-legitimize the risk of data science failure, employing methods such as persuasion, coercion, and leveraging power imbalances. Through her research, she seeks to develop a ground-up risk management framework that can effectively manage the risks of data science project failures and foster a more democratic work culture. Lahiri has 12 years of experience in the industry in India. She headed a risk management team in India before joining Syracuse.

**Jeffrey Saltz**
Jeffrey Saltz is an Associate Professor at Syracuse University, where he leads their graduate applied data science program. His research focuses on agile data science project management. Prior to joining Syracuse, Jeff reported to the global CIO at JPMorgan Chase, where he drove technology innovation across the bank. His previous roles at the bank included CTO consumer risk, Head of Risk Core Processing (within Chase Card Services) and the Chief Information Architect (across the consumer bank). Jeff holds a B.S. in computer science from Cornell University, an M.B.A. from the Wharton School at the University of Pennsylvania and a Ph.D. in information systems from the New Jersey Institute of Technology.

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# Project Change Canvas

**Raquel Ferreira**
MIEGSI, University of Minho
Campus de Azurém, 4800-058 Guimarães,
Portugal
rsm.ferreira@hotmail.com

**João Varajão**
ALGORITMI Research Centre/LASI, University of Minho
Campus de Azurém, 4800-058 Guimarães,
Portugal
varajao@dsi.uminho.pt

**Luis Silva Rodrigues**
CEOS.PP, ISCAP, Polytechnic University of Porto
Rua Jaime Lopes Amorim, S. Mamede de Infesta, Porto,
Portugal
lsr@iscap.ipp.pt

**Rui Dinis Sousa**
ALGORITMI Research Centre/LASI, University of Minho
Campus de Azurém, 4800-058 Guimarães,
Portugal
rds@dsi.uminho.pt

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**Raquel Ferreira**
MIEGSI, University of Minho
Campus de Azurém, 4804-533 Guimarães, Portugal
rsm.ferreira@hotmail.com

**João Varajão**
ALGORITMI Research Centre/LASI, University of Minho
Campus de Azurém, 4804-533 Guimarães, Portugal
varajao@dsi.uminho.pt

**Luis Silva Rodrigues**
CEOS.PP, ISCAP, Polytechnic University of Porto
Rua Jaime Lopes Amorim, S. Mamede de Infesta, Porto, Portugal
lsr@iscap.ipp.pt

**Rui Dinis Sousa**
ALGORITMI Research Centre/LASI, University of Minho
Campus de Azurém, 4804-533 Guimarães, Portugal
rds@dsi.uminho.pt

**Abstract:**
Project management plays a critical role in boosting the success of organizations' projects. However, no matter how well a project is managed, changes are inevitable during its execution. It is crucial to evaluate the impact of these changes before implementing them to ensure they do not compromise the project's success. Existing techniques for assessing the effects of changes have several limitations—particularly in their failure to account for how changes might affect various aspects of project management, such as scope, cost, time, resources, communication, risk, procurement, or overall success. To overcome this limitation, this article introduces a new technique – the *Project Change Canvas* – that enables the systematic assessment of changes in information systems and technology projects by identifying and weighing their potential impacts across all relevant project management knowledge areas.

**Keywords:**
project; information systems; information technologies; integrated change assessment; change; impact; success; canvas.

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## 1. Introduction

Project management is highly valuable in organizations [1][2] and is crucial to projects' quality and success [3][4][5], which has been traditionally defined in terms of meeting the initial budget, deadlines, and objectives [6][7]. However, leading projects to success can be a huge endeavor because, due to their complexity, there are many dynamic variables to take into account, including technical, behavioral, and contextual ones [8]. Furthermore, no matter how well a project is planned, changes will always occur, requiring one or more aspects to be reassessed [9][10].

In the literature, it is possible to find various definitions to describe the concept of "change" since it can be applied in different contexts, including organizational, project, and technological changes. Organizational changes can occur in the organization's structure and processes; technological changes can be related, for example, to the appearance or diffusion of new technologies or processes [11]. In this article, change is defined as any event that modifies the initially defined scope, execution time, costs, quality, or other project elements [12].

If changes are not controlled, the project may have negative consequences [1]. According to PMI [9][10], change control involves identifying, documenting, and either approving or rejecting changes to project documents, deliverables, or baselines. All changes must be evaluated to assess their impact on the project before making a decision [13]. It is, therefore, essential to have a process for controlling changes that may arise during the project lifecycle [14].

Hussain et al. [15] state that although the efficient management of changes to requirements is a critical aspect of software engineering, approaches in this area tend to be rudimentary. For their part, Vuorinen and Martinsuo [16] also point to the need for integrated change management since current techniques do not comprehensively and seamlessly address the various areas of project management.

This paper proposes a new technique that helps project managers identify and weigh up the impacts of requested changes before implementing them in the project. The developed technique, the *Project Change Canvas*, is a one-page canvas for describing and evaluating changes. The main purpose is to help weigh up the impact of required changes considering the various project management knowledge areas. Design Science Research was used to develop this technique.

This study contributes to project management by addressing a gap in change evaluation techniques. The *Project Change Canvas* systematizes the evaluation of the impact of changes on projects, something that has been done in a limited way until now (without considering all the fundamental aspects of a project). Furthermore, the canvas has the potential to substantially improve the way project managers deal with changes during project execution. By structuring the assessment of impacts, professionals can make more informed decisions, minimizing risks and maximizing the probability of project success.

Section 2 presents the grounding concepts of the research. Section 3 describes the research method. Section 4 presents the proposed technique, the *Project Change Canvas*. Section 5 discusses the evaluation of the new canvas. Finally, Section 6 presents some concluding remarks.

## 2. Background

### *2.1 Changes to projects*

Despite their temporary nature [17], projects usually experience a variety of changes throughout their life cycle [18][19]. To better understand the changes that occur during projects, it is necessary to be aware of the causes behind these changes, the types of changes that exist, and their associated impacts. According to Butt et al. [18], project changes can arise from a variety of reasons, whether caused by internal or external factors [16][20-23].

Mejlænder-Larsen [22] states that the client typically requests changes driven by external factors, whereas the project team originates changes related to internal factors. Love et al. [24] present a comprehensive view, highlighting those external environmental factors (of the organization), including Government Uncertainties, Economic Uncertainties, Legal Uncertainties, Technological Uncertainties, Institutional Influences, and Natural Causes. On the other hand, some internal environmental factors (of the organization) lead to project changes, such as project uncertainty, organizational uncertainty, financial uncertainty, human uncertainty, and conflicts of interest.

Bano et al. [25] in their research propose a different organization for the causes of (requirements) changes, classifying them as essential or accidental. The authors explain that essential causes are beyond the control of the work team or organization and result from factors like changes in market demand or the environment. Accidental causes, such as a vague product vision or strategy or a less-than-thorough business assessment, can be controlled and avoided.

In turn, Eckert et al. [26] distinguish between the different types of changes, namely initiated changes in the product and emergent changes throughout the product's life cycle. According to Mejlænder-Larsen [22], emergent changes occur spontaneously and are not planned or intentional. They arise from the product's properties [11] due to existing weaknesses in the product [26]. In contrast, initiated changes are planned and controlled [23], originating outside the product [11]. These changes may occur in response to new needs identified by the customer [26]. Thus, while initiated changes are accepted at any stage of the design process, emergent changes are often seen as negative for the project because they can cause delays [26]. This is justified because initiated changes are supported by more comprehensive knowledge than emergent changes [23].

In the study by Sjögren et al. [23], 55% of the project changes analyzed were emergent changes, while the rest were initiated changes. In the case of emerging changes, the average time from requesting the change to the decision being made was 103 days, while in the case of initiated changes, it was 56 days. Another finding of this study was that initiated changes had a higher rejection rate than emerging changes (32% and 15%, respectively). These figures suggest that emergent changes are the most frequent and urgent to address, as they are unplanned. However, because they are unplanned, it often takes longer to decide whether to accept them to prevent negative impacts on the project.

According to Ibbs et al. [27], not all project changes are negative. In fact, they can be implemented to reduce project costs, time, and difficulties. Additionally, changes can also occur to correct mistakes made during the project [22]. Typically, changes are made to enhance the product by addressing weaknesses and better fulfilling the customer's requirements [26]. On the other hand, these changes can be detrimental, as changes to the plan can affect compliance with the budget, as well as the duration of the project, either directly or indirectly [27], and impact negatively on the project's results [28].

When emergent changes occur in a project, costs typically increase due to the additional time and resources required [26]. According to Majerowicz & Shinn [29], the cost and schedule of a project are generally related; however, this does not imply that every extension of the project schedule results in increased costs. Most of the time, delays in the project are caused by other factors, which lead to increases in the project budget. Majerowicz & Shinn [29] point out that whenever there is an increase in the costs associated with the project, the project duration usually also increases, and vice versa. Similarly, when project risks become problematic, they typically result in schedule delays and cost overruns. As such, evaluating and controlling the impact of changes on projects is essential to avoid poor results.

### *2.2 Techniques and processes for evaluating changes in projects*

The full impact of project changes only becomes evident after they have been implemented [30]. If changes are not adequately controlled, they can lead to additional potentially causing negative impacts on the project [1]. The techniques and processes for evaluating changes identified in the literature are presented next.

According to PMI [9][10], integrated change control encompasses checking change requests, approving requests, managing changes to the project deliverables, the project management plan, and the project documents, and communicating decisions. The main advantage of this process is that it allows documented changes to be considered in an integrated manner while keeping the project's overall risk in focus. Changes are frequently made to the project without considering its overall objectives or plans and without measuring their impact. Therefore, a control process must be established to help the project manager and team monitor changes [14] and prevent and mitigate the risk of project failure.

Hussain et al. [15] propose a change management model that incorporates the types of formal changes and informal changes to requirements, thus representing more realistically the changes that arise in a project. This model assumes that some requested changes are handled with the client through informal conversations without a formal record (contract).

Bhatti et al. [20] suggest a formal method for the process of managing changes to requirements in a software development project, structured into six phases: initiation (requesting the change); reception (formally registering the change on a change request form); evaluation (assessment of the impacts of the change by the Change Control Board); decision-making (approval or rejection of the change); implementation of the change (in the event of approval); and configuration (list of the configuration parameters that were used to configure the change).

In turn, Xing [31] proposes a control process for managing change requests that closely resembles the model by Bhatti et al. [20], adding the baseline concept. This concept is defined as a desired value for a project dimension (e.g., scope, budget, schedule) or an agreed plan, which serves as a reference for comparison during project execution. Xing's model includes four steps: requesting the change, evaluating the change, accepting or rejecting the change, and, if accepted, implementing the change.

Mejlænder-Larsen [22] introduces a Change Control System (CCS) for managing changes, which is based on the five stages of the change management process (identification, submission, evaluation, approval, and implementation of the change) and Building Information Modelling (BIM) to assess the impact and consequences of the change at the evaluation stage. According to the author, the CCS is designed to store, control, report, and track project changes and deviations, facilitating the efficient processing of changes. In other words, when a design change request is made, it is submitted to the Change Control Board, where it is processed, categorized, evaluated, and either approved or rejected.

The study by Gaber et al. [14] outlines three approaches to monitoring and controlling projects based on various scheduling scenarios. It compares these approaches to demonstrate their effects on project cost and time. The first approach described is the Classic Approach, where costs and durations are allocated to each task in the project, serving as reference points for monitoring and control. These reference points are used to determine whether the tasks are carried out according to the schedule initially defined and to assess whether the project cost does not exceed the stipulated budget. The second approach referred to is Earned Value Analysis (EVA), used to objectively measure the project's progress. EVA enables the calculation of the Schedule Performance Index (SPI), which helps assess deviations from the original project schedule baseline, as well as the calculation of cost variances, and the Cost Performace Index (CPI), which measures the amount of work completed relative to the cost incurred. This analysis provides an integrated view of the project by measuring Planned Value (PV), Earned Value (EV), and Actual Cost (AC) [9][10][32]. The third approach discussed, Integrated Project and Change Management (IPCM), focuses on integrating change management and project management activities.

Isaac & Navon [30] propose a model designed to automatically identify the potential consequences of a change in a construction project at the time of the change request without requiring the actual implementation of the change. The model uses available information sources related to the project to assess the impact of changes on the project's cost, schedule, and performance.

The work by Hu & Liu [21] analyzes why changes arise in information technology projects and the impact of these changes, proposing a solution for change management and a process for implementing the proposed solution. This process includes a set of procedures for registering a change request and defining the steps to be considered according to the expected impact of the change.

According to Motawa et al. [33], several project elements must be considered when developing change management systems, as well as possible causes that could lead to project changes. The system proposed by the authors combines a change prediction model based on fuzzy logic with the Dynamic Planning and Control Methodology model, designed to evaluate the negative impacts of changes on construction performance.

Ibbs et al. [27] present a comprehensive project change management system founded on five principles: promoting a balanced change culture, recognizing change, evaluating change, implementing change, and continuously improving with lessons learned. Each of these principles interacts with the others to optimize the system.

The model proposed by Hao et al. [12] was developed by synthesizing various change management process models from the literature. This model consists of five sequential stages: identifying, evaluating and proposing, approving, implementing, and reviewing changes.

In summary, the techniques and processes analyzed do not consider all the areas of a project that can be impacted by the implementation of a change, usually focusing just on the cost, time, or quality of a project. Another limitation identified is that it is rare to find a description of how changes should be implemented.

## 3. Method

Design Science Research (DSR) was adopted to develop this work, following the six stages proposed by Peffers et al. [34]: identifying the problem, defining the objectives, creating a new artifact, demonstrating and evaluating the artifact, and communicating the results obtained.

In the first stage of the DSR, a literature review was carried out to develop an in-depth understanding of the types of changes that occur in projects and the associated causes and impacts. Existing techniques for assessing the impacts of changes and the current change management processes were also studied. This led to confirmation that a new proposal for change management was needed, as the existing techniques do not deal holistically with the assessment of change impacts. In the second stage of the DSR, after clarifying the state of the art and supporting the problem, the expected objectives for the new technique to be created were defined. Then, in the third stage of the DSR, the desired characteristics of the new technique were defined, and the respective artifact, the *Project Change Canvas*, was created. A detailed study of existing change control techniques in the literature was also carried out at this stage to identify best practices. The *Project Change Canvas*, in a simple and structured way, makes it possible to analyze and weigh up the potential impacts a change can have on the various areas of a project. The fourth stage of the DSR consisted in evaluating the *Project Change Canvas* in practice in two projects. The evaluation was carried out to test the new technique's relevance and identify improvement opportunities. Then, the objectives proposed for the technique were compared with the results obtained from its use, showing to be a valid solution for the problem. Feedback from project teams in a real-life context allowed the *Project Change Canvas* to evolve, giving rise to several versions. This article presents the most recent version of the canvas.

## 4. Project Change Canvas (or PM Change Canvas)

As aforementioned, project changes are inevitable and are often of significant importance to their progress. The literature review clarifies that it is necessary to adopt control processes for the changes that arise during projects and techniques to assess their impacts holistically. In this way, the possible negative consequences resulting from a change should be mitigated or even eliminated, and the positive impacts of its implementation should be exploited.

Although various techniques have been proposed in the literature, they only focus on the impact on scope, time, or cost, neglecting other equally relevant areas, such as risk, resources, or other success facets. Therefore, a new technique is required to allow project managers to identify and weigh up the impacts of a requested change in an integrated way before it is implemented so that it does not compromise the project's success.

The technique presented here, named *Project Change Canvas* (also called *PM Change Canvas*), is a one-page canvas for identifying the impacts of changes to a project. Its main purpose is to allow the various knowledge areas of project management to be considered in an integrated way using a single assessment technique. By filling in the canvas, whenever a change is required in the project, it is possible to reflect on the potential impacts caused without any area of the project being overlooked.

The canvas was designed considering the main stages of the change control process found in the literature, namely, the change request, the evaluation of the request, the decision-making, and the implementation of the change [12][20-22][31].

### 4.1 Description of the Project Change Canvas

Figures 2 and 3 show the final version of the *Project Change Canvas* (front and back of the canvas). The canvas can be downloaded at https://zenodo.org/records/13895163.

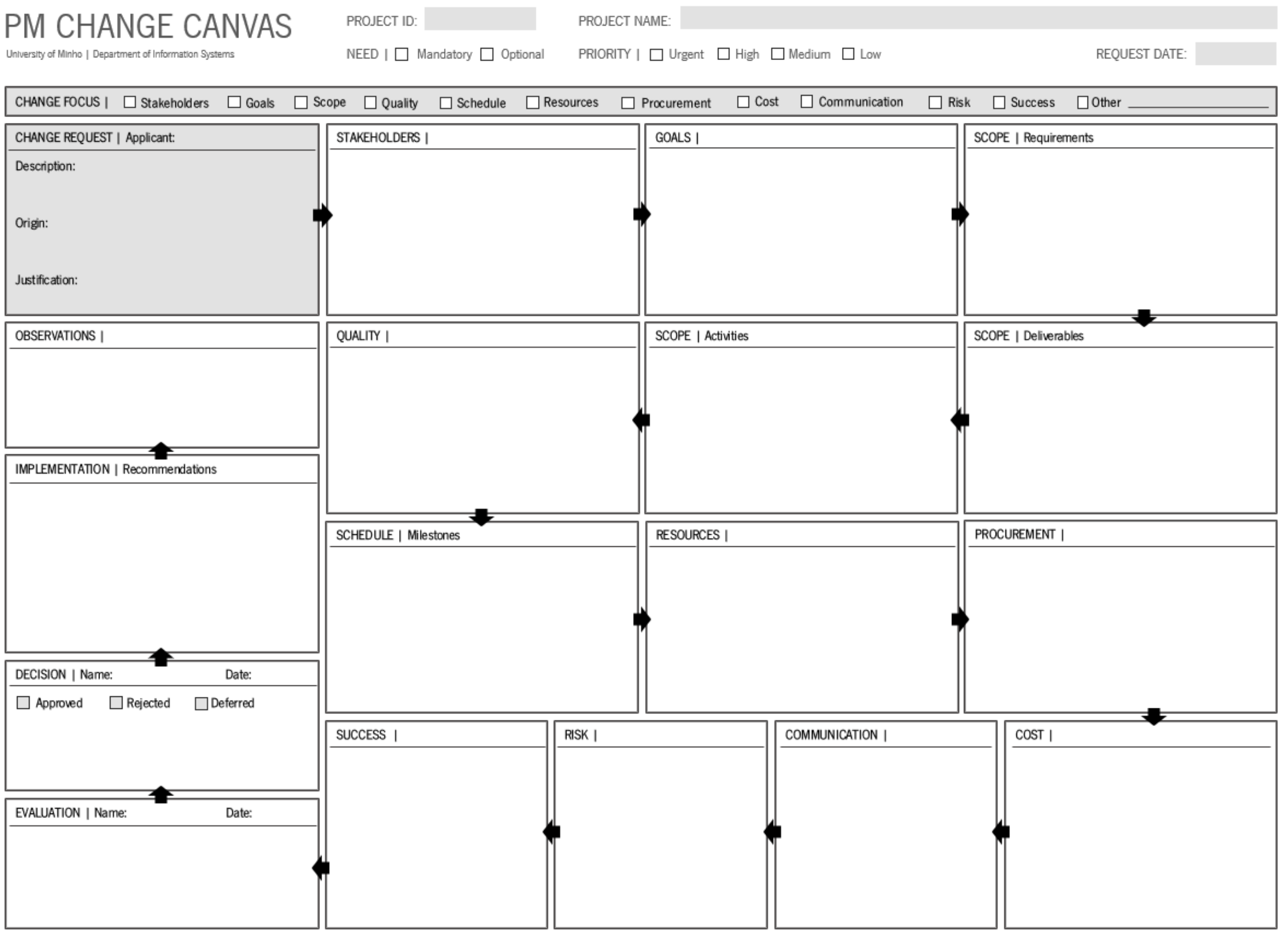


Fig 2. Project Change Canvas - Frontpage

After a change request, the first aspect of using the *Project Change Canvas* includes identifying the type of change, describing the change and its origin, and justifying the reasons for its implementation. According to Hao et al. [12], for an integrated change management system to be effective, it must consolidate all the information about the change, including causes, origin, impacts, action measures, change processes, relationships with other aspects of the project, hence the importance of detailing these aspects of the requested change from the very beginning of the process.

Next, there is a set of elements to consider (Stakeholders, Goals, Scope - requirements, Scope - deliverables, Scope - Activities, Quality, Schedule - milestones, Resources, Procurement, Cost, Communication, Risk, and Success), which correspond to the various areas of project management that may be affected by the implementation of the change. Here, an informed assessment of the possible impacts on each area is expected. According to Hao et al. [12], the assessment result should be a change proposal that summarizes the change and its impacts (e.g., a new updated action plan, cost, schedule, and other aspects of the project). In the *Project Change Canvas*, this impact is expected to be identified in each corresponding box. At the end of the assessment, the result of whether or not the change is feasible should be stated [20].

| EVALUATION | |
|---|---|
| STAKEHOLDERS | |
| GOALS | |
| SCOPE \| Requirements | |
| SCOPE \| Deliverables | |
| SCOPE \| Activities | |
| QUALITY | |
| SCHEDULE \| Milestones | |
| RESOURCES | |
| PROCUREMENT | |
| COST | |
| COMMUNICATION | |
| RISK | |
| SUCCESS | |
| EVALUATION | |

Note: Please write here, if you don't have more space in the stage 2 of the Canvas

**STEP 0 – HEADER**

| | |
|---|---|
| PROJECT ID | Specify the ID assigned to the project. |
| PROJECT NAME | Specify the name of the project. |
| NEED | Specify whether implementing the change is optional or mandatory |
| PRIORITY | Specify the priority of the change request.<br>*Urgent*: max period of __ working days to evaluate the change;<br>*High*: max period of __ to __ working days to evaluate the change;<br>*Medium*: max period of __ to __ working days to evaluate the change;<br>*Low*: max period of __ working days to evaluate the change.<br>**Observation**: these values serve as a reference to better categorize the change's priority level, and may vary depending on the type of project. |
| REQUEST DATE | Specify the date of the change request. |

**STEP 1 – CHANGE REQUEST**

| | |
|---|---|
| CHANGE FOCUS | Specify the type of change being requested (select only one option). |
| CHANGE REQUEST | *Applicant*: Specify the name of the person requesting the change.<br>*Description*: Brief description of the change.<br>*Origin*: Explain the reason for requesting the change.<br>*Justification*: Specify the reasons for implementing the change in the project. |

**STEP 2 – CHANGE REQUEST EVALUATION**

| | |
|---|---|
| STAKEHOLDERS | Identify the stakeholders who may be affected by the implementation of the change. New strategies for involving stakeholders in the decisions and implementation of the change can also be discussed. |
| GOALS | Specify (if applicable) which project goals/objectives will be impacted by the change. |
| SCOPE | *Requirements*: Specify the project requirements that will be affected by the change.<br>*Deliverables*: Specify the project deliverables (e.g., products or services) that will be added, removed, or modified with the change.<br>*Activities*: Specify changes to project activities, such as adding, subtracting, and/or changing the sequence, the duration of activities, or both. |
| QUALITY | Specify any changes in the project quality and possible control measures to be altered or implemented to ensure project quality. |
| SCHEDULE | *Milestones*: Specify any changes to the project milestones. |
| RESOURCES | Specify which resources will be required and/or affected when the change is implemented. These resources could be material or human. The assignment of the new activities (resulting from the change) to members of the project team can also be mentioned here. |
| PROCUREMENT | Specify (if applicable) which new contracting of products or services is needed. |
| COST | Specify whether there will be an increase, decrease, or no change in the project's cost. If possible, include an estimate of the cost increase or decrease. |
| COMMUNICATION | Specify the project communications that will be affected (e.g., monthly meetings will now be weekly). It should also be mentioned how the implementation of the change and its possible impacts will be communicated to stakeholders, including methods (e.g., email communication) and frequency. |
| RISK | Identify the risks that could arise from implementing the change and the impact on the project. |
| SUCCESS | Specify the benefits and drawbacks that can be expected from implementing the change, including success factors. |
| EVALUATION | Provide the assessment results of the impacts of the proposed change. It should include the *Name* of the person responsible for assessing the impacts and the *Date* when the assessment was carried out. |

**STEP 3 – DECISION MAKING**

| | |
|---|---|
| DECISION | Specify whether the change has been approved, rejected or deferred (if the change has already been evaluated, but there are no conditions for its implementation yet). If the change has been deferred or rejected, provide the reason(s) in the blank space.<br>*Name*: name of the person who made the decision or who has the required authority for that (typically, it should be the project manager).<br>*Date*: date when the status of the change was altered. |

**STEP 4 – CHANGE IMPLEMENTATION**

| | |
|---|---|
| IMPLEMENTATION \| Recommendations | Given the current state of the project, list the options for implementing the change, taking into account the existing constraints. |
| OBSERVATIONS | Include here any observations relevant to the implementation of the change. |

Fig. 3. Project Change Canvas – Backpage

The status of the change should then be recorded, indicating whether the change has been approved or rejected [20]. However, Ibbs et al. [27] add that, in most cases, more time is needed to decide whether to approve or reject a change, which is why the *Project Change Canvas* has three possible statuses for a change (approved, rejected, or deferred). If the change is approved, the project team must be notified to implement the change. Otherwise, if the request is rejected or remains pending, the reasons for this decision must be given [20].

Finally, the implementation of the requested change must be planned and coordinated considering all aspects of the project that are affected [22]; there is a box in the *Project Change Canvas* for writing down implementation suggestions.

### *4.2 Filling in the Project Change Canvas*

A different canvas must be used for each change request. In other words, if two changes are requested in a project, two canvases must be filled in. Typically, the project manager, together with the other team members (and possibly other project stakeholders), will fill in the canvas. Below is an explanation of the steps involved in filling in the various elements of the canvas. The canvases can also serve to log changes.

*Step 0 – Header*

When requesting a change to the project, one should start by filling in the Canvas header (figure 4):

- PROJECT ID – Specify the ID assigned to the project.
- PROJECT NAME – Specify the name of the project.
- NEED – Only one option should be chosen, indicating whether implementation of the change is optional or mandatory.
- PRIORITY – Specify the level of priority with which the change request should be handled, namely (the descriptions of the levels presented below are only examples and may vary according to the project):

  *Urgent*: the change must be dealt with immediately (e.g., maximum period of 6 working days to assess the change);

  *High*: the change must be dealt with as soon as possible (e.g., maximum period of 7 to 14 working days to evaluate the change);

  *Medium*: the change does not require immediate attention (e.g., maximum period of 15 to 30 working days to evaluate the change);

  *Low*: the change request has low urgency (e.g., a maximum period of 60 working days to evaluate the change).
- REQUEST DATE – Specify the date of the change request.

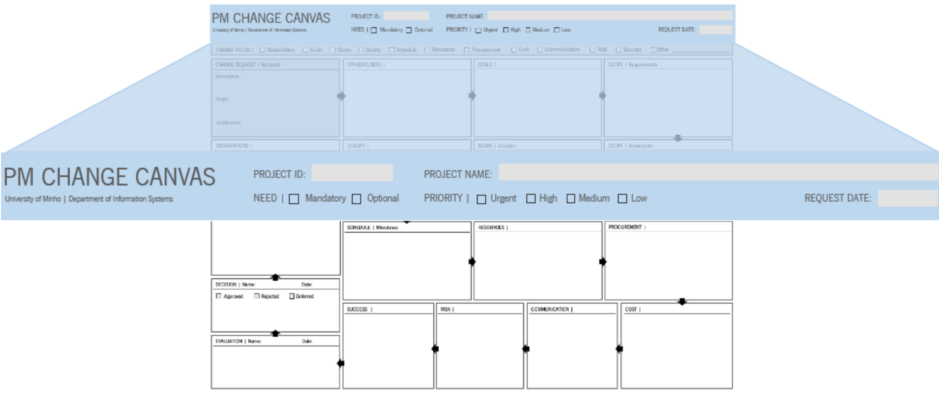


Fig. 4. Step 0 - Header

*Step 1 – Characterization of the change*

Next, it is necessary to fill in the focus of change and the details of the change requested:

- CHANGE FOCUS (figure 5) – Specify the focus of change that is being requested (e.g., Stakeholders, Goals, Scope, Quality, Schedule, Resources, Procurements, Cost, Communications, Risk, Success, or Other areas of the project). The focus of change must be selected from the existing options, and a change may be related to more than one knowledge area.
- CHANGE REQUEST (figure 6) – Fill in the details of the requested change:

  *Applicant*: Specify the name of the person requesting the change. The requester can be the client, a member of the team, the organization's management, or other stakeholder in the project.

  *Description*: Briefly describe and explain the change.

  *Origin*: Describe the reason for requesting the change.

  *Justification*: Specify the reasons for implementing the change in the project.

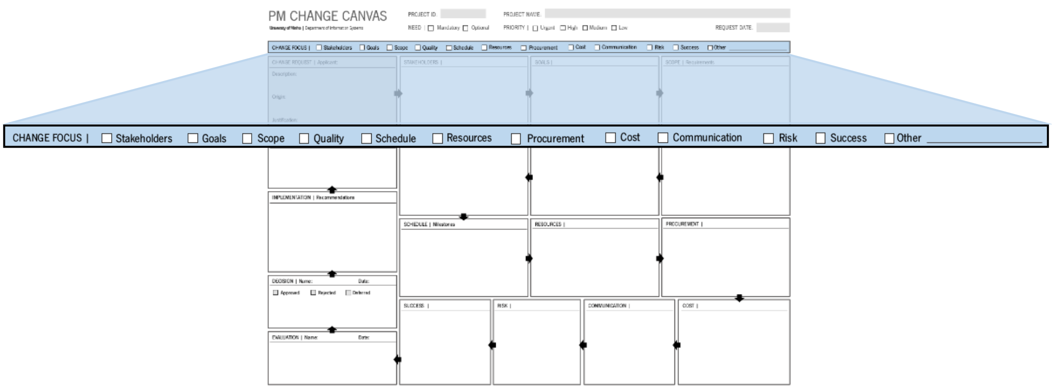


Fig. 5. Step 1 – Change Focus

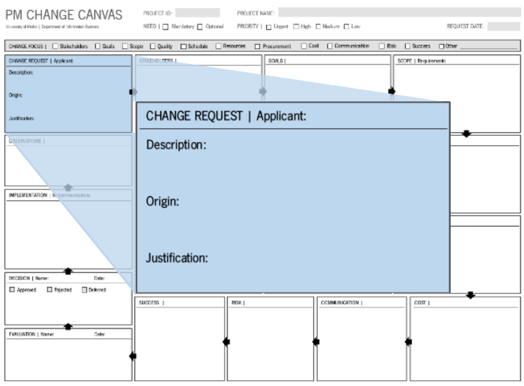


Fig. 6. Step 1 – Change Request

*Step 2 – Evaluation of the change request*

In step 2, the change request must be evaluated by analyzing the impact of the change on each of the project management knowledge areas (figure 7). The impact can be assessed using existing techniques in the literature (e.g., [14]). This stage gathers the necessary elements to evaluate whether the proposed change can be accepted and implemented. According to Kauffmann et al. [35], changes and impacts must be appropriately identified, discussed, and agreed upon by all parties interested in implementing the change.

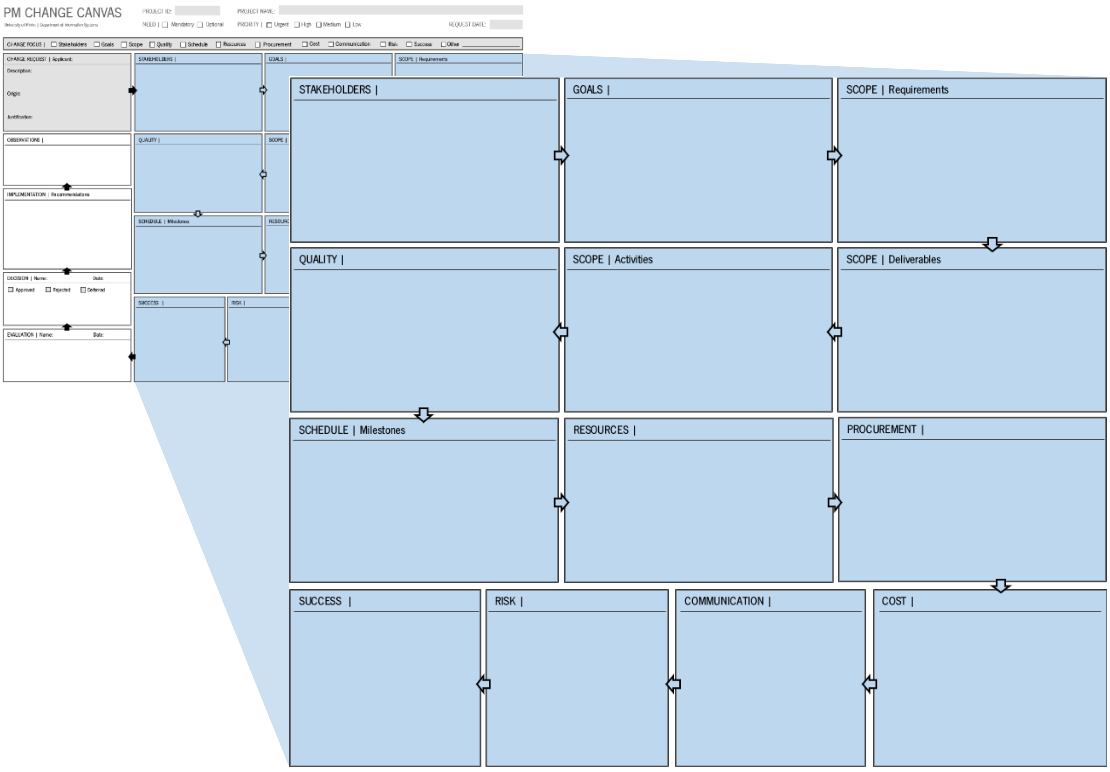


Fig. 7. Step 2 - Identifying and assessing the impacts of the change requested

The fields to fill in on the Canvas are (figure 7):

- STAKEHOLDERS – Identify the stakeholders who may be affected by the implementation of the change (including the appearance of new stakeholders). New strategies for involving stakeholders in the decisions and implementation of the change can also be discussed.
- GOALS – Specify (if applicable) which project goals/objectives will be impacted by the change (either by adding new objectives, modifying existing ones, or removing objectives).
- SCOPE | *Requirements* – Specify the project requirements that will be affected by the change (e.g., existing project requirements may be modified or removed, but new requirements may also arise as a result of implementing the change).

- SCOPE | *Deliverables* – Specify the project deliverables (e.g., products or services) that will be added, removed, or modified with the change.
- SCOPE | *Activities*– Specify changes to project activities, such as adding, subtracting, and/or changing the sequence, the duration of activities, or both.
- QUALITY – Specify any changes in the project quality and possible control measures to be altered or implemented to ensure project quality.
- SCHEDULE | *Milestones* – Specify any changes to the project milestones.
- RESOURCES – Specify which resources will be required and/or affected when the change is implemented. These resources can be material or human. The assignment of the new activities (resulting from the change) to members of the project team can also be mentioned here.
- PROCUREMENT – Specify (if applicable) which new contracting of products or services is needed (or changes in existing contracts).
- COST – Specify whether there will be an increase, decrease, or no change in the project's cost. If possible, include an estimate of the cost increase or decrease.
- COMMUNICATION – Specify the project communications that will be affected (e.g., monthly meetings will need to be weekly). It should also be mentioned how the implementation of the change and its possible impacts will be communicated to stakeholders, including methods (e.g., email communication) and frequency.
- RISK – Identify the risks that could arise from implementing the change and the impact on the project.
- SUCCESS – Specify the benefits and drawbacks that can be expected from implementing the change, including success factors.

Also, at this stage, an assessment of the identified impacts should be made, filling in the following fields (figure 8):

- EVALUATION – Provide the assessment results of the impacts of the proposed change.

  *Name*: Specify the name of the person responsible for assessing the impacts of the change or who has the necessary authority to sign the document.

  *Date*: Specify the date when the assessment of the impact of the change was carried out.

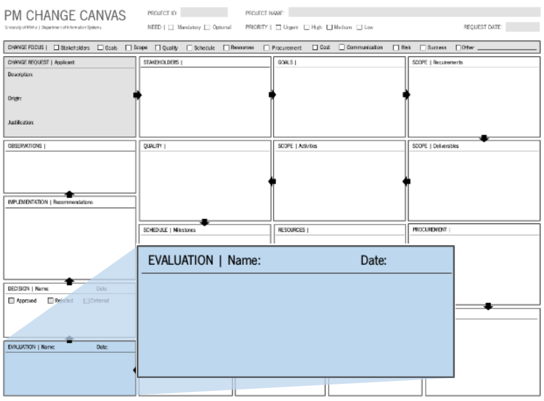


Fig. 8. Step 2 - Evaluation

*Step 3 – Decision-making*

After assessing the possible impacts of the change, a formal decision should be made, and it can be approved, rejected, or left pending (deferred). If approved, the work team should be notified to implement the change. However, if the change request is rejected or remains pending (if it is delayed), the person who requested it should be notified of the reasons for this decision. The fields to fill in are (figure 9):

- DECISION – Specify whether the change has been approved, rejected, or deferred (e.g., if the change has already been evaluated, but there are no conditions for its implementation yet). If the change has been deferred or rejected, provide the reason(s) in the blank space.

  *Name*: Specify the name of the person who made the decision or who has the required authority for that (typically, it should be the project manager).

  *Date*: Specify the date when the status of the change was altered.

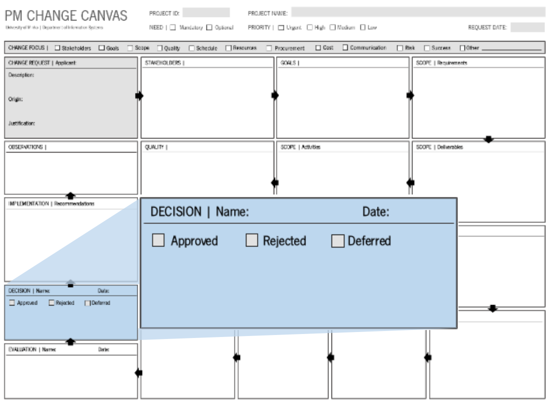


Fig. 9. Step 3 - Decision-making

*Step 4 – Implementing the change*

This stage, the last in the change control management process, refers to the implementation of the change, but it is only carried out if the change request has been approved in the previous stage. The fields to fill in on the canvas are (figures 10 and 11):

- IMPLEMENTATION | Recommendations (figura 9) – Given the current state of the project, list the options for implementing the change, taking into account the existing constraints.
- OBSERVATIONS (figura 10) – Include here any observations relevant to the implementation of the change.

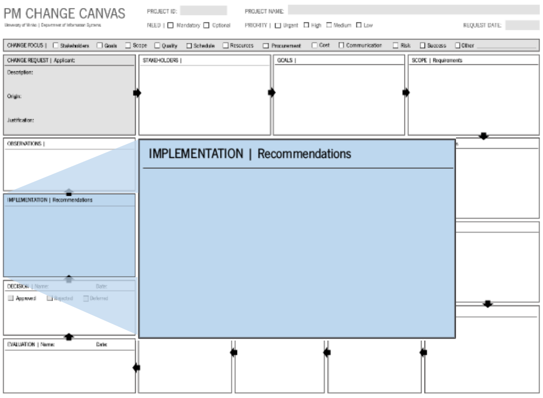

Fig. 10. Step 4 - Implementation suggestions

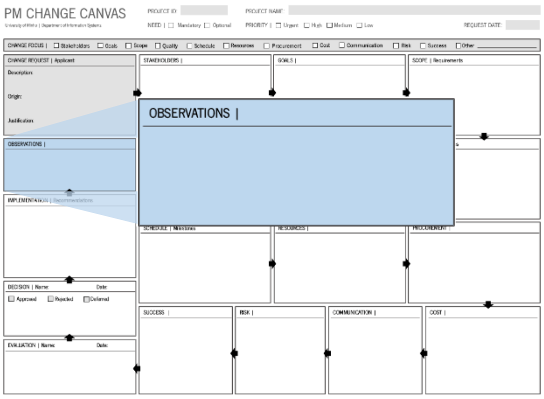

Fig. 11. Step 4 - Observations

## *4.3 Illustration of the Canvas application*

To illustrate the application of Canvas, Figure 12 presents an example that reflects the change request described next.

Let's consider a fictional project for a company with headquarters in Portugal that has the main objective of creating a new website in Portuguese (*PROJECT ID: "web-01"; PROJECT NAME: "New company website"*). However, given the company's need to reach and strengthen its presence in international markets (*JUSTIFICATION*), the project's client (*APPLICANT; STAKEHOLDERS*) in the middle of the project lifecycle requested an English version of the website (*ORIGIN; DESCRIPTION; GOALS*). The main requirement linked to this change request was the translation of the website (*SCOPE|Requirements*), with the content translation and the English version of the website serving as the primary deliverables (*SCOPE|Deliverables*). The client also stated that this request was mandatory (*NEED*) and asked to evaluate and implement this request as soon as possible (*PRIORITY*). Based on the change request's characteristics, it was determined that the focus of the change was related to the scope of the project (*FOCUS*).

Three activities were added to the project to implement this change request. The first activity is the translation of the website contents into English (*SCOPE|Activities*), which requires contracting translation services from an external company (*PROCUREMENT*). The timeframe set for this activity was one week (*SCHEDULE|Milestones*); however, it is essential to note that this limited timeframe may not be sufficient and can cause a delay in the project (*RISK*). On the other hand, the development of the Portuguese website was still ongoing, and the contents were not stable (*OBSERVATIONS*). The estimated cost of the translation services was €3500 (*COST*), and it was recommended that the company XPTO be contacted for this service, with whom the company has a good business relationship (*IMPLEMENTATION|Recommendations*). The second activity identified is the development of the website pages in English (*SCOPE|Activities*), which requires the collaboration of one of the website developers already allocated to the project (*RESOURCES*). This developer is also responsible for the third activity, which involves carrying out the necessary tests to validate the English version of the website (*SCOPE|Activities*). For these two activities, a timeframe of around three weeks was set (*SCHEDULE|Milestones*), and the costs were estimated at €2000 (*COST*).

The implementation of the change requested involves the verification of the translation of the content and the test of the English version of the website (*QUALITY*). In order to discuss the progress of the change implementation, it was decided to schedule some meetings with the client, the company responsible for the content translation, and other project members (*COMMUNICATION*). The success of the implementation of the change would depend on the client's satisfaction with the English version of the website and compliance with the scope, deadlines, and costs of the project (*SUCCESS*). The project member ("John Doe") responsible for change management evaluated the requested change and proposed that the change can only be implemented if the client agrees with the impacts on the project schedule and budget (*EVALUATION*). After evaluating the change request, the project manager ("Jane Smith") decided to defer the implementation of the change request until it had been approved by the Client (*DECISION*).

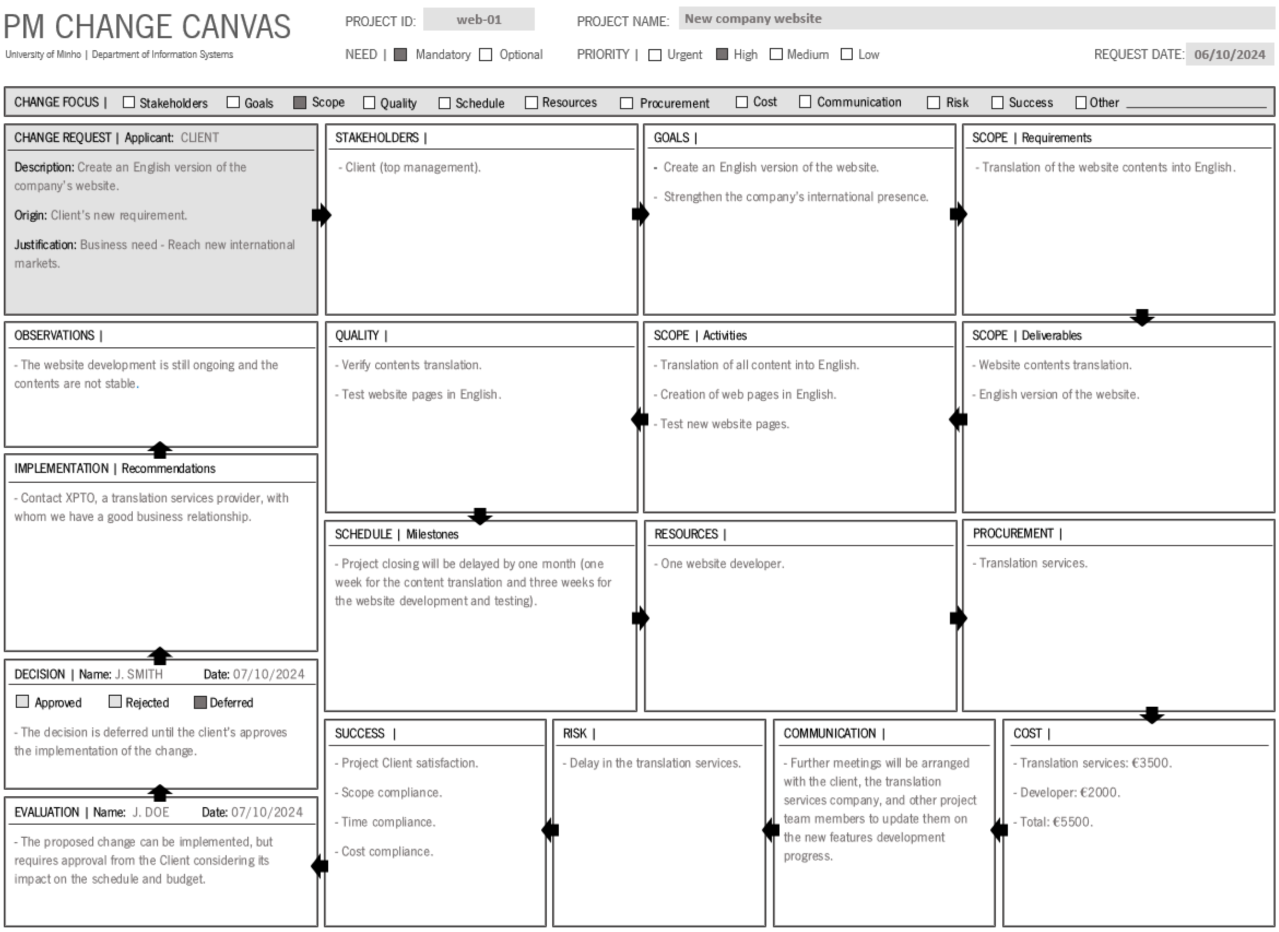


Fig. 12. Canvas Example

## 5. Evaluation and discussion

Two real-world projects (evaluations 1 and 2) were used to evaluate the canvas. The final version of the canvas reflects improvements considering the project teams' opinions.

The first evaluation took place in a project aimed at improving the workflow of a journal. The main objectives were to improve the efficiency and effectiveness of the journal's management process, reduce the time involved in administrative tasks, and improve the service provided to the journal's authors and readers. The *Project Change Canvas* was used in the context of a change of scope requested by the client. The change involved the creation of a Portuguese version (duplicated) of the journal's website, which was only in English (according to the requirements initially established).

The second evaluation was carried out in a project aiming to develop a set of software modules needed for an existing application. The expected results for this project consisted of a description of the process, various software modules, and a support manual for the user. The change in which the *Project Change Canvas* was used involved altering the content management system to another platform. This request came from the work team.

Table 1 shows the feedback and evaluation of the *Project Change Canvas* obtained from the members of each work team in the aforementioned projects, summarizing the main advantages and disadvantages perceived by the project teams. After collecting feedback from the working teams, the various suggestions for improvements to the *Project Change Canvas* were analyzed and discussed. It was concluded that some issues needed to be addressed. One of these shortcomings, which was very evident, was the absence of a field that focused on how the change implementation would affect the project's success. In this way, one of the elements of the canvas, originally labeled "Responsibilities" was replaced by "Success". The area of success was seen as very pertinent to the canvas since its purpose is to allow the weighing-up of the change impacts on the various project areas without compromising any success facets. The "Responsibilities" area did not prove useful since it referred to each stakeholder's responsibilities. Therefore, this topic is now covered in the "Resources" area since project resources also include human resources.

Table 1. Feedback on *Project Change Canvas*

| Evaluation/ Project | Team member | Advantages | Disadvantages |
|---|---|---|---|
| 1 | A1 | ▪ Covers all project areas that may be affected by the change.<br>▪ Succinct organization of the project areas. | ▪ Does not incorporate the project's success.[1] |
| | A2 | ▪ Easy to use.<br>▪ Focuses on crucial project areas.<br>▪ Helps to discuss possible impacts with stakeholders more easily.<br>▪ Allows you to summarize everything on just one page. | ▪ Some elements of the Canvas are confusing (lack of descriptions).[2]<br>▪ Small fields/boxes.[3]<br>▪ Does not incorporate the "non-scope" and the project's success.[4] |
| | A3 | ▪ Covers all project areas that may be affected by the change.<br>▪ It makes it possible to weigh up the impacts without overlooking relevant areas of the project.<br>▪ Allows for the synthesis of the most relevant information for making a decision. | ▪ Highly developed technique, which can be exhausting to fill out.<br>▪ It may not be suitable for all types of projects.<br>▪ Does not incorporate the project's success.[1] |
| | A4 | ▪ Allows a clearer visualization of the possible impacts caused by the change. | ▪ This can lead to rapid and rushed analysis, which can result in erroneous assessments of the project's impact.<br>▪ Does not incorporate the project's success.[1] |
| | A5 | ▪ Provides an overview of the impact of changes in each area of the project.<br>▪ Facilitates understanding of impacts by project stakeholders. | ▪ Does not incorporate the project's success.[1] |
| 2 | B1 | ▪ Allows for better organization of the impacts of the change, avoiding negative consequences on the project.<br>▪ Well structured. | ▪ The fact that it is a paper sheet restricts the space of the descriptions.[3]<br>▪ Each change requested involves starting a new sheet. |

| Evaluation/ Project | Team member | Advantages | Disadvantages |
|---|---|---|---|
| | B2 | ▪ Just one sheet.<br>▪ Easy to use.<br>▪ Allows a better perception of the impact. | ▪ Lack of a detailed description of how to fill in each field.[2] |
| | B3 | ▪ Easy impact analysis. | ▪ Implies ISO 21502 or PMBOK previous knowledge.[2] |
| | B4 | ▪ Just one sheet.<br>▪ Covers most project areas.<br>▪ Objective process.<br>▪ Allows a summary assessment of the impacts in each of the project areas. | ▪ Implies one change per sheet.<br>▪ Lack of a field for final feedback on the change.[5] |
| | B5 | ▪ Intuitive.<br>▪ Easy weighting of impacts. | ▪ Lack of a detailed description.[2] |

[1] In the final canvas version, a new element related to success was added.
[2] In the final canvas version, an explanation of how to fill it in was added to the back page of the canvas.
[3] In the final canvas version, an extra space was added to the back of the canvas for filling in.
[4] In the final canvas version, a new element related to success was added, but it was not considered appropriate to include the "non-scope"since it ccan be mentioned in the scope box.
[5] In the final canvas version, a new element related to the observations was added.

The lack of descriptions to help with the *Project Change Canvas* use was also cited as an original weakness, requiring an explanation of how to fill in the canvas. It was, therefore, decided to include instructions on the back of the Canvas. The limited space to detail the assessments was also mentioned, and it was decided to address this issue by adding more space on the back of the sheet. Another option to consider in the future is to make the canvas available digitally. The lack of a field for final feedback on the change was also resolved by adding a field for comments, allowing final considerations to be recorded.

Another disadvantage mentioned by the teams was the complexity associated with Canvas, since it requires knowing the ISO 21502 [36] or PMBOK [10] fundamentals. However, a project manager is expected to have this consolidated knowledge – therefore, this was not seen as a barrier. The new descriptions included on the back of the *Project Change Canvas* also help overcome this difficulty. The fact that each change request involves starting a new canvas process was also seen as a disadvantage. However, it was clear from the review that each change should be treated as unique, requiring an individualized request process [21].

On the other hand, the advantages the project team members pointed out are also considerable. For example, the canvas allows for a more exhaustive reflection of the change before it is implemented, without essential areas of the project being forgotten; it provides for an integrated visualization of the possible impacts of the change on the various knowledge areas of the project; it is well structured and intuitive to use, which makes it easier to visualize the areas affected by the change; it only uses one page. Other advantages of the canvas that have not been mentioned but can be considered are that it allows for a centralized record of all the information relating to the requested change, which can serve as a future reference and translate into beneficial learning (lessons learned). The labels chosen for canvas blocks align with ISO 21502 [36], making it easier for users to use and know.

Summing up, the project teams considered the proposed technique an asset to the project, as it enabled them to carry out a detailed analysis and weighting of the impacts of each change on the various areas of the project. In their opinion, the use of the *Project Change Canvas* is intuitive. It makes it possible to easily visualize and reflect on the impacts comprehensively without any area of the project being overlooked. The canvas supports decision-making by helping to accept or reject the implementation of requested changes to the project. It also makes communicating the impact assessment results easier for the project's stakeholders.

## 6. Conclusion

Project changes are inevitable, and there must be mechanisms for evaluation and control so that the project's success is not compromised. The main contributions of this work are the clarification of the various changes that occur in information technology/information systems projects, as well as their potential impact, and the review of the methods and techniques currently proposed for their assessment and control. Moreover, this paper proposes a new technique that enables a holistic and integrative evaluation of the possible impacts caused by project changes. As its main practical contribution, the new canvas helps project managers assess and foresee impacts caused by project changes. The canvas also supports teaching by emphasizing the need to consider the impact of various changes on projects without any area of project knowledge management being overlooked.

As a limitation, it should be noted that the evaluations carried out were focused on information technology/information systems projects and were limited to two projects. For future work, we suggest creating a software application to support the *Project Change Canvas* and applying it to projects in other areas.

**Acknowledgments**

A previous version of this study, published in the Portuguese Conference of Information Systems, is available in Portuguese language. However, please note that the canvas presented here is an improved and extended version.

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## Biographical notes

**Raquel Ferreira**
Raquel Ferreira graduated from the University of Minho with an integrated master's degree in Engineering and Management in Information Systems. She is currently working as an Information Technology/Information Systems consultant.

**João Varajão**
João Varajão is currently a professor of Information Systems (IS ) and Project Management (PM) at the University of Minho. He is also a researcher at the ALGORITMI/LASI centre. His current research interests are IS PM and IS Development (addressing IS and PM success). He has published numerous refereed publications, authored books, edited books, and published book chapters and communications at conferences. He serves as editor-in-chief, associate editor, and member of committees for conferences and international journals.
ORCID: 0000-0002-4303-3908

**Luis Silva Rodrigues**
Luis Silva Rodrigues is a professor of Information Systems at the Polytechnic University of Porto. He is also a researcher at the CEOS.PP centre and his research interests are Business Process Management, Enterprise Engineering, and IS Project Management. He is a board member of the Portuguese Association of Information Systems. He has published refereed publications, authored books, conference communications, and others.

**Rui Dinis Sousa**
Rui Dinis Sousa holds a Ph.D. in Management Information Systems from the University of Georgia, USA. He is a researcher at the ALGORITMI/LASI Centre and coordinates the Information Systems and Technologies for the Transformation of Organizations and Society laboratory. His research focuses on business-IT alignment, IT governance, IT-driven organizational development, and enterprise engineering. He teaches Business Process Management, Enterprise Architecture, and Enterprise Systems courses. Rui Dinis is also a member of the Portuguese Association of Information Systems board. He has authored refereed journal articles, conference communications, book chapters, and edited books. ORCID: 0000-0001-7607-555X.

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