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Integrating Industry 4.0 Technologies into Project Management: A Framework Proposal

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Abstract

INTRODUCTION: The integration of Industry 4.0 technologies and Project Management represents a paradigm shift from traditional, experience-based practices to data-driven and intelligent systems. By leveraging advanced tools such as Artificial Intelligence, Big Data analytics, Internet of Things and Digital Twins, Project Management processes become increasingly predictive, adaptive and efficient.
OBJECTIVES: The objective of this study is to understand the main impacts of Industry 4.0 technologies and tools on the improvement of Project Management. There is limited research on the impacts and improvements brought by Industry 4.0 in Project Management, making it an interesting gap to study. It is also intended to propose a conceptual framework to guide the integration of Industry 4.0 tools into Project Management practices.
METHODS: A Systematic Literature Review was conducted using a mixed methodological approach, combining an inductive investigation approach, an exploratory research nature and grounded theory as the research strategy.
RESULTS: The results indicate that the application of Industry 4.0 technologies and tools improves Project Management. Regarding the technologies and tools of Industry 4.0 applied to enhance Project Management outcomes, Artificial Intelligence, Big Data and Building Information Modelling emerged as the key ones. Among the main impacts and improvements resulting from the integration of these technologies into Project Management, the enhancement of the decision-making process and tasks automation stands out. A correlation matrix was developed between Industry 4.0 technologies and the impacts/improvements generated in Project Management. Additionally, a framework for integrating Industry 4.0 and Project Management was proposed, based on the principles of continuous improvement.
CONCLUSION: This framework is relevant for researchers, organizations, project managers and their respective teams who aim to enhance Project Management in the Industrial Revolution paradigm.

Keywords: Project Management, Industry 4.0, Technology Management, Decision-making, Digital Transition

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1. Introduction

In some organizations, Project Management remains, to this day, a highly bureaucratic process, characterized by limited innovation and low levels of technological integration. In such contexts, Project Management is often associated with delays, reflecting a misalignment between planning and actual execution. This aspect affects not only project performance but, more importantly, to the perception and credibility of Project Management, both within and outside organizations [1].

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Based on a preliminary review of the literature, it is shown that the fourth industrial revolution has introduced a wide range of technological transformations [2,3].

Those technologies contribute not only to the development of new projects related to process automation and digitalization, but also to the enhancement and evolution of Project Management practices across different activity sectors [4].

Project Management has evolved continuously over the years, particularly in response to successive industrial revolutions. In this context, it becomes essential to analyse how to enhance the work of professionals in this field by seeking a balance between established models and tools, industrial experience and emerging technological trends [5]. Project Management operates within a dynamic and complex environment, largely driven by the transformations associated with Industry 4.0 [6–8]. This scenario requires project managers to adopt a more proactive role and to develop new technical and behavioural competencies, enabling a transformation in how organizations manage their projects. The digital revolution, characterized by rapid technological advancement, is reshaping production, management and operational processes across multiple industries worldwide. This transformation represents an innovative approach aimed at integrating technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, Augmented Reality (AR) and Cloud Computing across a wide range of knowledge domains [1].

Industry 4.0 is founded upon key pillars such as innovation, automation and process digitalization, leveraging advanced technologies while recognizing that the primary asset of any organization remains its people [9,10]. For instance, IoT systems enable the interconnection of machines, individuals and data; thereby facilitating decision-making based on standardized criteria and reducing human subjectivity. Thus, Industry 4.0 technologies can change the way organizations operate and manage projects, with the potential to enhance process efficiency and enable the development of highly customized products and services [9].

Also, Project Management constitutes a critical field across organizations of all sizes and sectors. Its effectiveness has a direct impact on the ability of organizations to achieve strategic objectives, foster innovation and remain competitive in an ever-evolving business environment. As Industry 4.0 technologies continue to evolve, Project Management is undergoing a substantial transformation, driven by the new tools, methods and approaches designed to address emerging challenges and capitalize on the opportunities associated with digitalization and automation [11].

Thus, the transformations introduced by Industry 4.0 in the field of Project Management act as the primary motivation for this study. Such changes require a comprehensive understanding of the technologies and tools associated with Industry 4.0, as well as the training of professionals involved in Project Management. Also, there is a need to develop more dynamic Project Management practices, fully integrated with these emerging technologies. It is also essential to consider organizational investments to ensure that Industry 4.0 generates positive impacts on Project Management and that intended outcomes are effectively achieved.

Thus, it is intended to investigate and analyse existing bibliographic sources by means of a Systematic Literature Review (SLR), with the aim of understanding and deepening the scientific relevance of Industry 4.0 within Project Management. One of the main objectives is to identify the aspects most widely recognized by researchers and practitioners in the field, within this new disruptive and technology-driven paradigm.

This study seeks to establish a current and well-founded reference framework based on scientifically relevant publications, supporting the research in this domain. Another motivating factor for this study lies in the timeliness of the topics addressed, particularly Industry 4.0. As Industry 4.0 is characterized by the integration of digital technologies, it demands more flexible Project Management approaches, such as Agile methodologies, which emphasize adaptability and iterative development, and are increasingly adopted, particularly in dynamic and technology-driven industries.

2. Material and Methods

This research is based on a SLR, which involves the development of a reproducible and structured research process. It draws upon a range of sources, including scientific articles, books and book chapters, peer-reviewed conference proceedings, web-based content, and other sources of scientific relevance related to the topic [12].

In this context, the main objective of the study is to conduct a SLR on the relationship between Industry 4.0 and Project Management. Accordingly, the following research question was formulated:

"What are the main impacts of Industry 4.0 technologies and tools on the improvement of Project Management?"

The planning process of the SLR was based on the Preferred Reporting Items for Systematic Reviews (PRISMA) methodology, which consists of a set of guidelines designed to support the SLR reports. According to the PRISMA flow diagram, the stages for identifying the scientific documents to be analysed in the SLR are [13]:

(i) Identification: The database selected for the literature search was defined, as well as the search parameters used to retrieve scientific documents from the chosen platform (Table 1).

(ii) Screening: Criteria were defined to evaluate the scientific documents identified in the selected database, which were subsequently subjected to content analysis for thematic exploration.
Inclusion criteria: In this step, the search criteria were established, guiding the screening process and determining the selection of scientific documents to be included in the research database.
Exclusion criteria: In this step, three types of exclusion criteria were defined (Table 2). Duplicated records,

documents for which full-text access was unavailable, and documents not related to the topic were excluded.

Table 1. Search parameters for scientific documents in the selected database

Description	Attribute	Justification
Keywords	"*Project Management*" "*Industry 4.0*"	Core keywords of the investigation correspond to the terms representing the two knowledge domains intended to be related and analysed.
Publication period	From 2013 and onwards	The publication period was defined from 2013, when the term Industry 4.0 gained global prominence following the Hannover Fair in Germany
Publication status	Final	Only documents in a final publication state were considered, to avoid changes or updates in the dataset during the selection process.
Research field	Engineering	The selected publication area was Engineering, as it corresponds to the field of study.
Types of documents	All types, except for brief research notes and editorial notes	Brief research notes were excluded, as these documents may not contain information validated through a peer-review process. Systematic review articles were also excluded, as they represent secondary sources in which authors have already performed at least one cycle of qualitative analysis and data filtering.
Language	English	English was adopted as the language criterion, as it is the most used language for scientific publication and content analysis.

Table 2. Exclusion criteria for the searched scientific documents

Exclusion Criteria	Coding	Parametrization
Duplicated	DUPL	Scientific documents listed as duplicates in the selected database were removed. This may be due to certain publications being first presented, for example, at conferences and then indexed in proceedings or published as book chapters.
Unavailable full-text access	SATC	Scientific documents for which full-text access could not be obtained for content analysis. These mainly correspond to documents that remained inaccessible even through the Online Knowledge Library (*B-on*) used by Portuguese universities.
Not related to the research topic	NRTP	Scientific documents that, after reading and content analysis, were found not to be related to the research topic.

The inclusion criteria comprised peer-reviewed scientific documents indexed in *Scopus*, published between 2013 and 2025, written in English, classified within the Engineering subject area, published in final form, and containing the terms "Project Management" and "Industry 4.0" in the title, abstract, or keywords. Scientific documents were excluded if they corresponded to duplicated records, lacked full-text accessibility, or were identified as not directly related to the intersection between Industry 4.0 and Project Management following the screening and content analysis stages.

2.1. SLR Implementation

The *Scopus* database was selected because it is one of the largest and most comprehensive peer-reviewed literature databases. This is due to the broad scientific coverage, multidisciplinary scope and strong representation of peer-reviewed publications in the fields of Engineering, Technology Management and Industrial Systems. In Engineering-related research, Scopus is widely recognized as one of the most comprehensive and frequently adopted indexing databases, covering several high-impact journals, conference proceedings and scientific publications relevant to Industry 4.0 and Project Management.

Another important factor supporting the selection of Scopus is its advanced search and filtering capabilities, which enable the development of reproducible and structured search strategies aligned with PRISMA guidelines. Scopus allows precise filtering by subject area, publication stage, document type, language and publication year; thereby increasing methodological consistency and transparency in the screening process.

The "Scopus Document Search" was used to structure and conduct the searches. Accordingly, the search strategy developed and applied within the Scopus database resulted in the following query syntax:

TITLE-ABS-KEY ("Project Management" AND "Industry 4.0") AND PUBYEAR > 2012 AND (LIMIT-TO

(PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA, "ENGI")) AND (EXCLUDE (DOCTYPE, "sh") OR EXCLUDE (DOCTYPE, "re") OR EXCLUDE (DOCTYPE, "cr")) AND (LIMIT-TO (LANGUAGE, "English")).

After completing the screening process of the 113 retrieved documents, 79 records were excluded, leaving 34 documents eligible for inclusion in the qualitative data analysis stage. Figure 1 presents the PRISMA flow diagram of the SLR implemented.

The analysis revealed that 38% of the selected studies employed a case study methodology, while 23% reported the development of conceptual models and frameworks, some of which focused on the evolution of the different industrial revolution eras, as well as their associated technologies and tools.

Within the selected documents of the SLR, the construction industry is the sector in which the application of Industry 4.0 technologies and tools for the improvement of Project Management is most frequently reported, accounting for approximately 40% of the selected studies. Construction projects involve multiple stakeholders, fragmented processes, making them suitable for the application of Industry 4.0 technologies such as Building Information Modelling (BIM), IoT and data analytics. Additionally, the sector's relatively low level of digital maturity offers significant potential for transformation. Given the high costs and frequent delays associated with construction projects, even small improvements can generate substantial benefits, attracting both academic research and industry interest in enhancing efficiency and performance [14–16].

Nevertheless, the information technology sector represents 12%, followed by the automotive sector, engineering project-based firms and the manufacturing sector, which account for 8% of the sectors, respectively.

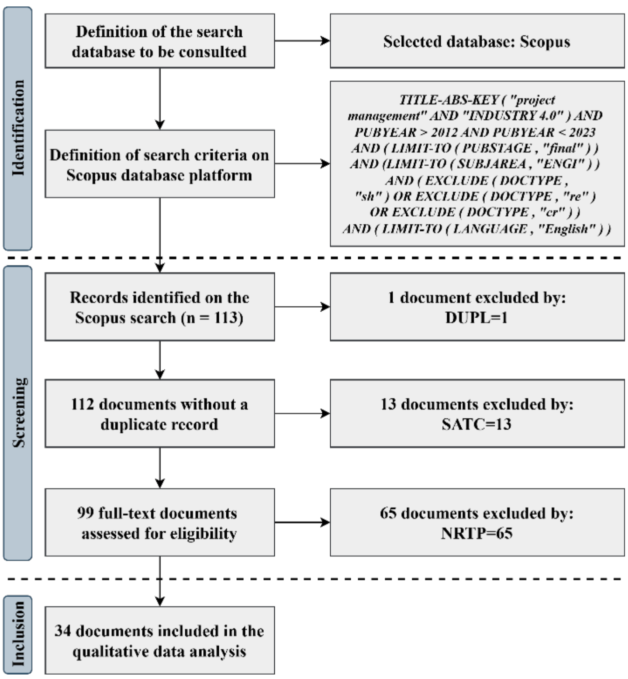

Figure 1. PRISMA flow diagram of the SLR implementation approach

2.2. Content Analysis

Content analysis is widely used to interpret textual data with the aim of identifying patterns, thematic categories, and underlying meanings.

According to [17], content analysis can be defined as "*a research technique for making replicable and valid inferences from texts to the contexts of their use*". This definition highlights its systematic nature and applicability, mainly in qualitative contexts, enabling researchers to extract meaning from large volumes of verbal, written or visual data. The analysis provides a framework for interpreting the literature included in the SLR. By defining clear units of analysis - such as words, phrases or thematic segments - and establishing coding schemes grounded in theory or research questions, researchers can minimize subjective bias and ensure that their categorizations are replicable. In this sense, the coding carried out during the SLR design phase is of great importance in reducing ambiguity and strengthening the rigor of both the review process and subsequent content analysis.

This methodological clarity not only enhances reproducibility but also provides a documented record supported by the body of literature consulted [18]. The coding process followed predefined classification criteria; however, no formal inter-rater reliability coefficient was calculated. Thus, content analysis enriches the narrative of an SLR by synthesizing both explicit content (articulated themes) and latent content (implicit concepts). Regarding the quality evaluation criteria for content analysis, a careful reading was carried out to classify the documents regarding their contribution to the ongoing research. A classification scale divided into three points was adopted, defined as: Low contribution (one point), Medium contribution (three points) and High contribution (five points). Table 3 describes each of the established classification levels.

Table 3. Classification of the contribution

Classification	Contribution Level
Low Contribution (one point)	Documents that superficially address Industry 4.0 technologies or tools and their impact on improving Project Management, without significant details about specific tools or benefits.
Medium Contribution (three points)	Documents that provide details on how Industry 4.0 technologies or tools impact the improvement of Project Management, but do not offer a complete analysis of the benefits of Industry 4.0 in improving Project Management.

Classification	Contribution Level
High Contribution (five points)	Documents that provide comprehensive details on how Industry 4.0 technologies and tools impact the improvement of Project Management, offering a complete and in-depth analysis of the benefits of Industry 4.0 in improving Project Management.

It was found that 27% of the documents were assigned a "High" contribution classification and 35% were assigned a "Medium" classification. Approximately 38% of the documents were classified as having a “Low” contribution. Although the research topic is framed within the current context of Industry 4.0 and Project Management, this high percentage was maybe due to the lack of topic exploration, especially regarding the benefits of adopting Industry 4.0 technologies and tools to improve Project Management results. For the same reason, strategically, a classification system for the documents selected in the SLR process was defined during the development of the dissertation.

Figure 2 presents the bibliometric map obtained with *VOSviewer*® based on the keywords that have at least 2 occurrences in the scientific documents selected in the research. The network shows the keywords (represented by circles of different diameters), which visually represents the number of keywords occurrences of selected documents. The clusters identified were:

- Cluster 1 (“Project Management”): include Project Management, IoT, software design, budget control, 3D printers, manufacturing technologies, agile Project Management, life cycle, automation, digitization, manufacture and innovation;
- Cluster 2 (“Industry 4.0”): include Industry 4.0, artificial intelligence, risk management, business model, empirical studies, factor analysis, industrial research and knowledge management;
- Cluster 3 (“Competition”): include competition, information management, smart manufacturing, decision-making, embedded systems, cyber-physical systems and data handling;
- Cluster 4 (“Construction industry”): include construction industry, construction management, construction projects, project team and architectural design;
- Cluster 5 (“Industrial revolutions”): include industrial revolutions, human resource management and managers.

Overall, the map depicts that research is moving toward the integration of advanced digital technologies, intelligent manufacturing systems, agile and technology-driven Project Management approaches as well as human and organizational management practices

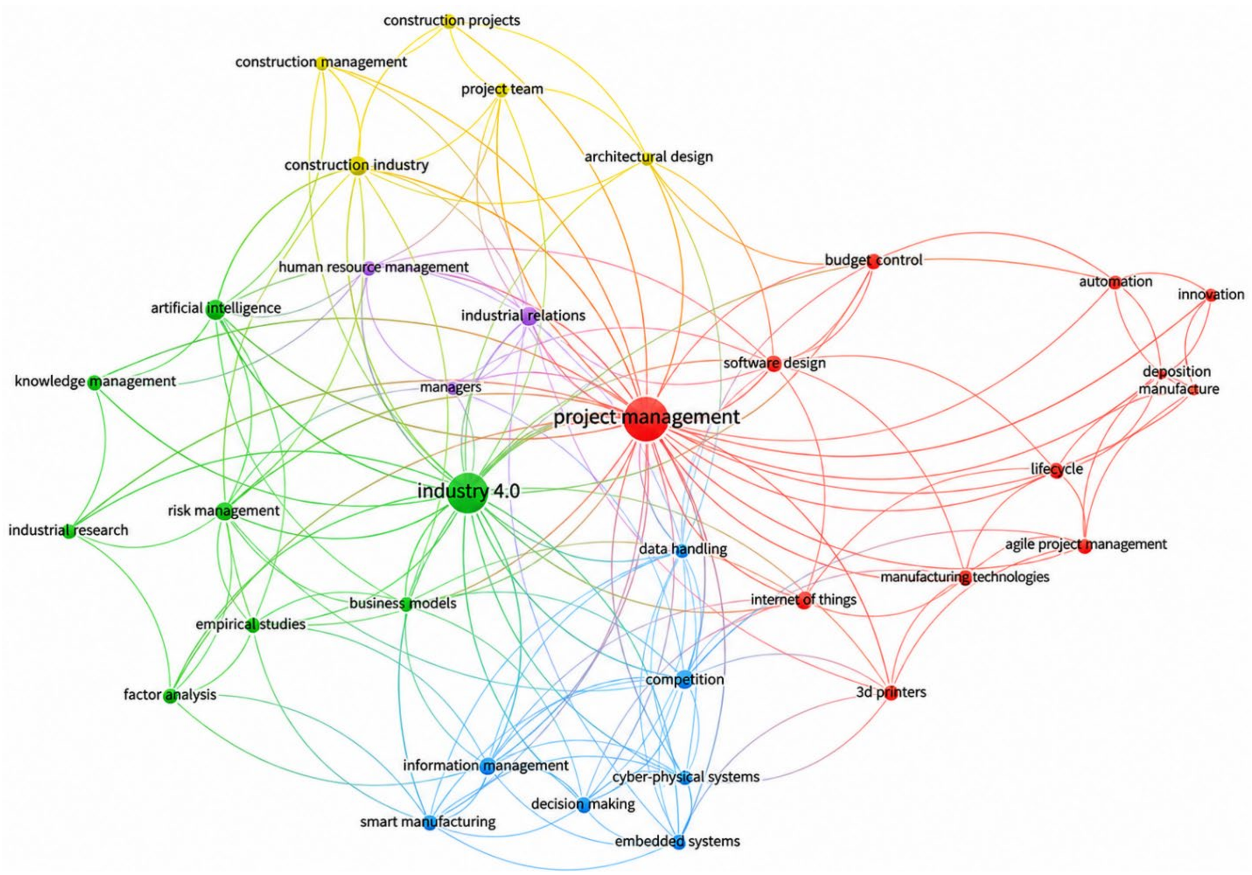

Figure 2. Bibliometric map obtained with VOSviewer®, considering the keywords of the documents selected in the SLR

3. SLR Results

In this section the main findings from the SLR are presented considering the identification of Industry 4.0 technologies and tools, as well as their impacts and improvements on Project Management. The main findings should support the framework for integrating Industry 4.0 tools with the improvement of Project Management.

3.1. Industry 4.0 Technologies

By analysing the Industry 4.0 technologies and tools cited in the selected scientific documents, it is observed that the most frequently mentioned are AI, IoT, Big Data, and BIM (see Figure 3). The findings suggest not all documents explicitly specify the Industry 4.0 technologies and tools employed.

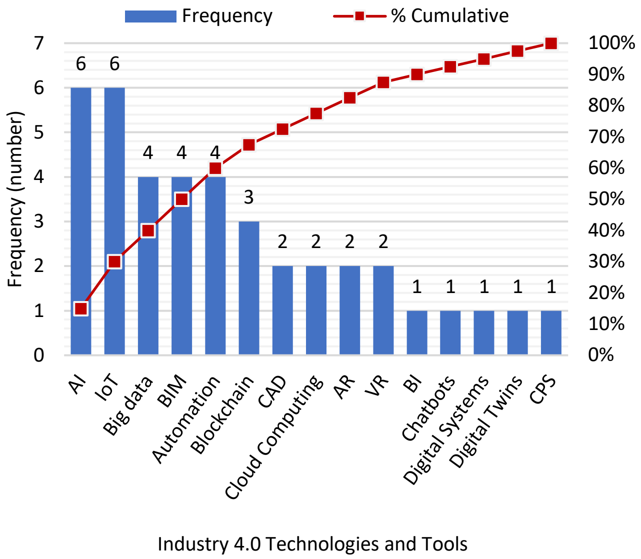

Figure 3. Most frequently referenced Industry 4.0 technologies and tools

AI Systems

According to [19], Project Management can be supported by applying AI, especially in the automation of routine tasks and in assisting anomaly detection. Authors in [20] argue that, using AI, project planning can be implemented more efficiently, as information collected from previous projects with similar structures can be used by AI systems to automatically generate work plans for future projects. This is achieved through the systematic use and analysis of historical project data, resulting in more accurate planning of project activities. According to [21] and [22], the composition of future project teams is expected to change significantly with the introduction of AI algorithms as team members. In this context, the capacity and availability of human team members can be redirected towards creative problem-solving activities.

Once a problem is resolved, human teams can transfer knowledge and learning outcomes back to the AI system, supporting continuous improvement.

Thus, it is necessary to transform traditional Project Management into an intelligent system by integrating cyber-physical systems and digital twins. This framework enables real-time monitoring of project progress [23].

IoT Technology

According to [24], IoT technology enables project managers and their teams to access real-time project resource data, facilitating improved resource management and greater transparency for stakeholders. This real-time access allows for more accurate allocation and use of resources, thereby improving schedule and budget performance. In maintaining activities, sensors monitor machinery performance, predicting needs to prevent costly downtime and delays. With IoT, projects can be monitored in real-time; for example, the installation of sensors and connected devices enables tracking inventory, human resources and project accomplishment status. Additionally, periodic capture of photos and videos from the site allows continuous monitoring of project delays [25].

Big Data

Based on [26], Project Management in industrial contexts is benefiting from the application of Big Data by enhanced project monitoring and control, with the primary objective of identifying potential issues before they occur and thereby improving efficiency. Big Data can assist project managers in identifying several risks, such as inefficiencies in employee or subcontractor performance, as well as financial risks associated with projects.

BIM

BIM was developed to provide information support for project activities [27]. Authors in [28], describe BIM as one of the main approaches enabling the digitalization of construction projects, with significant potential for information sharing, visualization, and the management of design changes.

During project execution, BIM can be used as a baseline for progress tracking and for visualizing discrepancies. Furthermore, the research proposed in [27] note that the integration of BIM with AI leads to improved outcomes in data retrieval processes, thereby enhancing the support provided to Project Management and execution within the construction industry.

3.2. Impacts on Project Management

To better understand the impacts of Industry 4.0 technologies on Project Management, it is important to systematically scope some definitions:

- Decision-making: Informed decisions based on pre-processed data.

- Task Automation: Automatic implementation of tasks, based on control systems.
- Real-time Monitoring: Continuous and immediate tracking of project status.
- Cost Reduction: Decrease in project execution expenditures.
- Risk Management: Identification, analysis and mitigation of potential risks.
- Procurement Processes' Agility: Faster purchasing and acquisition processes.
- Market Competitive Advantage: Creation of a differentiating factor compared to other organizations.
- Execution Time Reduction: Decrease in the time required to complete the project.
- Anomaly Detection: Detection of issues or deviations in the project for correction.
- Inter-project Communication: Improved exchange of information between different organizational projects.
- Incident management: Incidents supervision, from occurrence to resolution.

By analysing the impacts and improvements provided by Industry 4.0 technologies and tools in Project Management, it can be observed that the most frequently cited impacts and improvements are enhanced decision-making, task automation, real-time monitoring, and cost reduction (Figure 4). It is important to note that some documents do not specify the impacts or improvements resulting from the application of Industry 4.0 technologies and tools in Project Management.

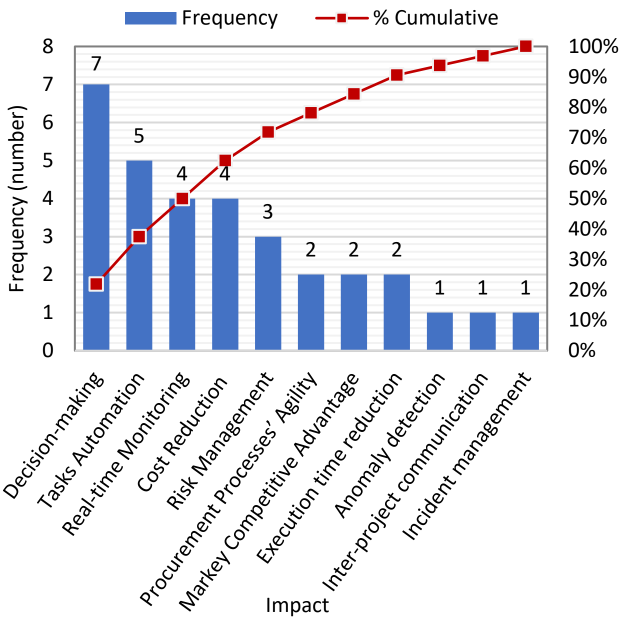

Figure 4. Most frequently referenced impacts of Industry 4.0 technologies on Project Management

Decision-making

The use of Industry 4.0 technologies and tools enables informed and agile decision-making, as the rapid collection, availability and analysis of data improve the decision-making process within Project Management, thereby enhancing the outcomes to be achieved.

According to [24], Blockchain and IoT technologies are emerging as promising solutions for improving the agility of project resource management processes, providing clear visibility into critical areas and supporting timely and effective decision-making.

The study published in [29] highlights that that BIM provides quantitative data and information to estimate the duration and cost of construction processes, serving as a more reliable basis for decision-making during early planning phases and sessions, as well as offering an intuitive means of visualizing project status.

According to [30], the use of simulation and Virtual Reality (VR) constitutes a starting point for decision-making regarding the launch of new projects in the context of Industry 4.0, as well as for associated risk management. Using virtual models that replicate real-world conditions became possible to anticipate areas for improvement in starting/future projects, by addressing shortcomings prior to their practical implementation.

Task Automation

The use of Industry 4.0 technologies and tools enables improvements in task automation, making repetitive and previously executed activities more efficient and increasingly automated.

According to [19], project managers' expectations often exceed the actual outcomes achieved through the implementation of Industry 4.0 technologies and tools in Project Management. Nevertheless, AI can be effectively applied to support Project Management by automating routine tasks and assisting in the identification of anomalies within projects.

The authors in [31], note that, although the adoption of Industry 4.0 technologies and tools may introduce cybersecurity risks, the rationalization of decision-making enabled by automation in Project Management is of greater significance. According to [20], the use of Industry 4.0 technologies, particularly AI, allows for the automated execution of project planning processes in a more efficient manner, through the collection and the use of data or information from similar past projects.

Real-time Monitoring

The use of Industry 4.0 technologies enhances real-time monitoring of project status, enabling the immediate identification of issues and deviations during project execution. This facilitates proactive decision-making and rapid response, ensuring that projects are completed within established cost, time and scope constraints.

Integrating Cyber-Physical System (CPS) with digital twin systems helps project managers in monitoring project progress in real-time.

Such integration enables the prediction and detection of bottlenecks, delays, failures and even potential future issues through the analysis of real-time data. The developed system supports proactive actions and decisions, such as predictive maintenance, project interruption and capacity expansion [23].

According to [26], the application of Big Data in Project Management within the construction industry enables real-time communication and status updates between the project site and the organization's headquarters. This contributes to faster and more agile responses to on-site issues, facilitating the identification of flaws and their root causes, and supporting the achievement of project objectives related to time, cost, quality and safety.

Cost Reduction

The application of Industry 4.0 technologies and tools enables project managers to exercise greater control, thereby supporting performance improvement and the reduction of project-related costs.

According to [32], the development of dynamic and adaptive schedules through automation, by incorporating real-time information on task execution durations, minimizes delays and, ultimately, contributes to overall cost reduction in projects.

The study conducted by [33] examines the use of Computer-Aided Design (CAD) based documentation integrated with information systems to establish a project planning and control system based on predefined rules, aimed at monitoring and reducing execution costs.

It is also important to emphasize that improved risk management contributes significantly to cost reduction. The early identification, analysis and mitigation of potential risks help to avoid high rework and/or repair costs, which are often incurred when anomalies are detected only after the project completion. According to [34], AI enhances communication across different projects within an organization, enabling the early identification, analysis and mitigation of potential risks.

4. Framework Proposal

This section presents the results from cross-referencing the SLR results, being developed a correlation matrix and proposed a conceptual framework.

4.1. Integration of Industry 4.0 Technologies and Project Management

Figure 5 presents the correlation matrix between Industry 4.0 technologies and the impacts/improvements identified as relevant to Project Management. The "X" indicates that evidence of an association between a specific technology and a particular impact or improvement in project management has been identified in the selected scientific documents. Evidence from the literature indicates that decision-making is enhanced by technologies such as AI, IoT technology, Big Data, BIM, Blockchain, Automation Systems, CAD and VR. Due to their potential to provide real-time data, enable predictive analytics and support simulations, these technologies allow Project Management teams to make strategic decisions in a more informed way.

Task Automation, enabled by AI, IoT, Big Data, BIM, process automation, CAD, and cloud computing, reduces manual workload and increases efficiency in the execution of Project Management activities.

Real-time Monitoring made possible by technologies and tools such as IoT, Big Data, BIM, CAD, cloud computing, digital twins and CPS allows project teams to continuously track project status, enabling fast responses to deviations and potential failures, thus helping to avoid delays and unnecessary costs.

Cost Reduction has become a priority and a fundamental constraint in Project Management. In this regard, technologies such as IoT, Automation Systems, CAD and digitization facilitate the minimization of waste during project implementation. Yet, the cost of implementing these technologies can be high, considering both investment and operational costs over the project's life span, requiring return-on-investment period analysis.

Risk Management, supported by technologies and tools such as AI, IoT, Big Data, Blockchain, Cloud Computing, and AR, assists project managers and teams in identifying and mitigating potential risks associated with projects. This can be achieved through stochastic risk modelling and learning-based approaches. In fact, machine learning-based forecasting can improve the operational resilience and reduce uncertainty in project outcomes.

Procurement Processes' Agility, enabled by IoT, Big Data, Blockchain, automation systems, Business Intelligence (BI), and chatbots, accelerates project acquisition and purchasing activities.

Market Competitive Advantage promoted by AI enables organizations that adopt this technology in their Project Management processes to develop a distinctive differentiator in the market. By embedding AI capabilities into Project Management processes, organizations and companies can exploit advanced data analytics, implement forecasting models, as well as automation to achieve higher operational performance and market differentiation.

Execution Time Reduction, facilitated by BIM, AR, VR, and digitization, decreases the time required for project completion by allowing effective task planning, resulting in smoother activity sequencing without interruptions.

Anomaly Detection, enabled by AI, allows the identification of issues and/or deviations in the project that can be corrected to ensure that planned tasks and objectives are effectively achieved and delivered.

Inter-project Communication, supported by AI, improves information exchange between different projects within the organization, enhancing management processes, particularly through improved planning of future projects based on lessons learned from completed ones. Management enabled by Big Data, facilitates the incidents management from its occurrence throughout the process to problem's resolution.

Impact/ Improvement	Industry 4.0 Technologies														
	AI	IoT	Big data	BIM	Blockchain	Automation	CAD	Cloud Computing	AR	VR	BI	Chatbots	Digitalization	Digital Twins	CPS
Decision-making	X	X	X	X	X	X	X			X					
Tasks Automation	X	X	X	X		X	X	X							
Real-time Monitoring		X	X	X			X	X						X	X
Cost Reduction		X				X	X						X		
Risk Management	X	X	X		X			X	X						
Procurement Processes' Agility		X	X		X	X					X	X			
Market Competitive Advantage	X														
Execution Time Reduction				X					X	X			X		
Anomaly Detection	X														
Inter-project Communication	X														
Incident Management			X												

Figure 5. Correlation matrix identifying Industry 4.0 technologies can be applied in the context of Project Management

4.2. Framework Structure

To provide project managers with a structured and conceptual framework to support the process of integrating Industry 4.0 technologies and tools into Project Management, a six-stage guidance proposal was conceptualized, partially based on the principles of continuous improvement methodology Plan, Do, Check, Act (PDCA). PDCA is a continuous improvement tool used in Quality Management, Project Management and Manufacturing, used to solve problems and implement innovation in a cyclical procedure [35].

The main idea is to propose a structured and iterative approach that enhances problem-solving and decision-making in Project Management through a framework based on six key stages. It allows planning the project actions based on clear objectives and real-time data, executing tasks on a controlled scale or within defined phases, while monitoring and evaluating project results. By fostering evidence-driven decisions, standardize effective practices or adjust strategies, it is possible to obtain advantages from digitization technologies, encouraging ongoing refinement throughout the project life span.

Figure 6 presents the flowchart of the proposed framework, so called as IPIREC-4PM – *Identification, Planning, Integration, Review, Evaluation, Consolidation for Industry 4.0 Project Management.*

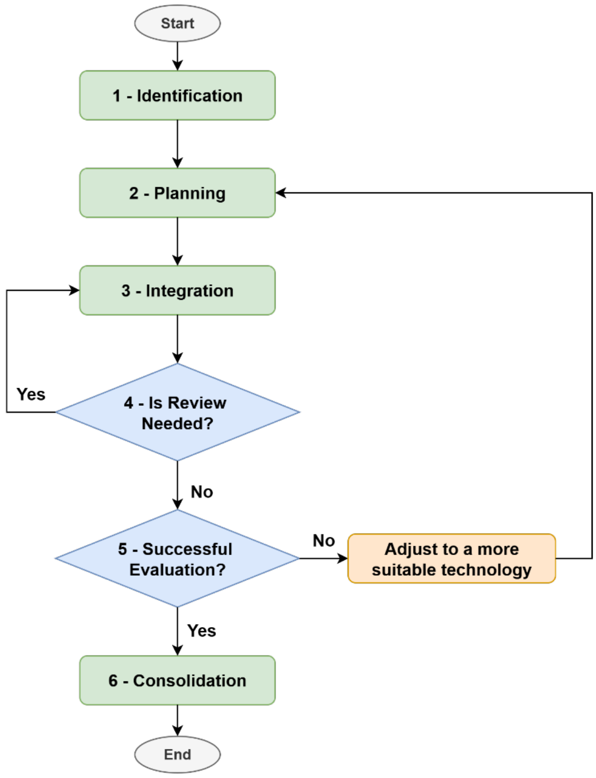

Figure 6. IPIREC-4PM model for integrating Industry 4.0 technologies and tools into Project Management

1 - Identification (I)

In this stage, the project manager should seek to understand the main deficiencies and opportunities for improvement within the Project Management process. For this purpose, performance indicators may be employed to determine areas for intended improvement and the corresponding implementation priorities. During this phase, it is strongly recommended to consult the results presented in Figure 4, as these may provide insight into which Industry 4.0 technologies could be implemented and integrated into Project Management to achieve improvements. Once the main opportunities for improvement have been identified, the process should proceed to the planning phase.

2 - Planning (P)

Having identified the Industry 4.0 technologies required to achieve improvements, the project manager, must conduct a demanding analysis and formulate a detailed action plan for its implementation and integration into Project Management. This process may require the involvement of several organizational departments and teams, making cross-departmental engagement essential to enhance the implementation success rate. The project manager should also perform a technical-economic analysis of the proposed technology or tool, providing a return-on-investment analysis to demonstrate its economic viability. Also, the expected benefits and impacts should be clearly defined.

3 – Integration (I)

This stage concerns the effective integration of the chosen technologies into Project Management procedures, thereby attaining the intended benefits and improvements for both Project Management practices. During this stage, it is essential to verify the alignment between what was planned and what has been delivered. The planned deliverables and the allocated financial resources should be verified.

4 – Revision (R)

Throughout the integration of Industry 4.0 technologies into Project Management, predefined milestones should be employed as well as control points to assess conformity between planned and actual outcomes. Any identified deviations must trigger a review process to readjust deliverables with the original project specifications, supported by corrective actions when needed, thereby ensuring continuous alignment and quality assurance across the implementation process.

5 – Evaluation (E)

Following the review process, the outcomes of integrating Industry 4.0 technologies into Project Management must be evaluated against the initial plan, by using predefined performance indicators. This evaluation may include comparing performance indicators such as schedule adherence, budget compliance, achievement of project deliverables and deadlines and budgets. The results from this evaluation must pinpoint areas for improvement, before and after the integration of Industry 4.0 technologies and tools.

Any deviations should be analysed to determine their causes and to assess the continued suitability of the implemented technology or tool. Where the solution remains viable, the original plan should be revised to correct discrepancies, thereby ensuring the intended improvements in Project Management performance.

6 – Consolidation (C)

Upon confirming that the integration of Industry 4.0 technologies into Project Management has achieved the planned outcomes, the consolidation procedure should be adopted. This involves standardizing and documenting the implemented procedures to support current project teams, enable undergoing analyses and identify potential improvements. Once consolidated, the strategy can be replicated in other projects with similar scope, representing a key benefit of the model as a structured, transferable methodology, provided that the established technological integration requirements are met.

It is important to note that the framework is presented as a literature-grounded proposal intended to guide future empirical testing, case studies and expert validation. At this stage, its value lies in organizing fragmented findings into a coherent implementation pathway, rather than in claiming superior predictive or validated performance.

Thus, a roadmap structured into different phases can be projected for assessing the practical applicability of Industry 4.0 technologies in Project Management through the IPIREC-4PM framework. The first phase involves the identification of the Project Management dimensions to be analysed, as well as the preparation of data collection. The second phase focuses on developing a mapping model capable of linking Industry 4.0 technologies with Project Management and organisational practices. This includes establishing a classification that associates the technologies with the areas of planning, monitoring, communication and risk management. Then, it is required to identify the levels of digital maturity and technology skills of teams and their managers to set a plan. All the data needs to be documented as well as the improvements and challenges achieved in project performance. The alignment with the IPIREC-4PM framework needs to be evaluated. The objective is to assess the framework’s practical applicability, identify potential gaps and refine its structure based on empirical evidence. Finally, validating and disseminating the results through pilot applications, practitioner-oriented guidelines and training activities, thereby supporting the broader adoption of Industry 4.0 technologies in Project Management contexts.

5. Study Contribution and Discussion

The present study does not claim to be the first to address Industry 4.0 tools in Project Management. Rather, its contribution is the systematic integration of both areas: a technology-impact correlation matrix and a conceptual framework (IPIREC-4PM).

As the framework is derived from literature rather than empirical testing, it should be interpreted as a conceptual proposal that requires future validation through case studies and expert evaluation.

The number of documents on the topic indicates growing scholarly interest, but it does not necessarily provide an operational pathway for integrating both topics; this is precisely the gap addressed by the present study. Thus, there is limited research on the impacts of Industry 4.0 on Project Management, making it necessary to reconsider current practices and how Project Management is influenced by this industrial revolution.

Industry 4.0 demands additional competencies that extend beyond technical skills, encompassing personal and social aptitudes. Project managers must be proficient in procedural, social and soft skill competencies, as well as capable of managing multiple teams. In fact, project managers and their teams face, and will continue to face, emerging challenges that evolve with the rapid advancement of technologies associated with this industrial revolution.

The adoption of agile methodologies is increasingly advocated as the optimal framework for project success. Integrating these practices necessitates a recalibration of managerial competencies, diverging significantly from the traditional leadership models emphasized in contemporary academic curricula[36].

Recent studies on agile methodologies in Project Management emphasize that agile approaches are evolving from purely software-oriented practices into broader organizational and hybrid management models capable of supporting digital transformation, AI integration, and adaptive decision-making [37]. The study conducted by [38]concludes that hybrid agile environments depend strongly on people-centred capabilities, agile mindset, organizational culture, communication, openness to change, collaboration, and continuous improvement. The successful agile Project Management is not achieved only through technical frameworks, but through organizational support and interpersonal competencies that enable teams to remain adaptable and resilient in complex project environments.

Agile methodologies are being enhanced through AI integration, giving rise to what the authors define as the "Intelligent Agile" paradigm [37]. In tec context of Project Management, AI-supported agile practices improve sprint planning, backlog prioritization, risk management, efficiency, and data-driven decision-making [39]. Thus, Agile approaches are transitioning from reactive approaches towards predictive and adaptive Project Management systems capable of anticipating risks and optimizing decision-making processes in real-time [37].

The capacity-building should begin with the project managers' academic training. The applicability of Industry 4.0 technologies should be explored with the objective of improving project outcomes and management practices and, thereby, better equipping professionals who are preparing to act, or who are already acting, as project managers [40].

The skills expected of a project manager in the context of Industry 4.0 are based on their ability to solve problems and act as an integrating asset [41].

A practical example is presented in the study by [28], which investigated the benefits of introducing and applying Industry 4.0 technologies and tools in the teaching of Project Management. The study found that the use of these technologies and tools improved both performance and the competencies required to manage projects, enhancing not only academic performance but also better preparing students for the practical challenges of the labour market.

The application of Industry 4.0 technologies to improve Project Management is not often discussed or implemented, representing a gap in the development of knowledge in both academic research and practical adoption. While Industry 4.0 has transformed manufacturing and operations by the integration of digital technologies such as AI, Big Data, IoT and CPS, its potential to transform Project Management practices has not been equally researched. This disconnect limits the field's ability to benefit from improved decision-making, real-time monitoring, predictive analytics and enhanced collaboration. The proposed correlation matrix supports this argument. The correlations' distribution suggests that Industry 4.0 technologies are not uniformly applied across Project Management. Instead, certain technologies exhibit stronger convergence with strategic, operational and monitoring-oriented Project Management activities. Despite the limitations of the matrix – the inability to measure the strength of relationships, causality or implementation maturity – supports the argument that Industry 4.0 does not merely digitize Project Management processes, but transforms how projects are planned, monitored, coordinated and controlled.

Moreover, the pace of industrial revolutions has accelerated considerably over time. Unlike previous transitions, which unfolded over decades, the current technological evolution is occurring at a speed up rate. Even so, several organizations, industries and even academies demonstrate a limited capacity to absorb, adapt and operationalize these innovations in an effective way.

Organizational inertia, resistance to change, lack of digital competencies and insufficient integration strategies often hinder the translation of technological potential into practical outcomes. As a result, a substantial gap emerges between the state-of-the-art technological possibilities proposed by Industry 4.0 and the actual practices observed in Project Management across sectors. This misalignment constrains both the performance and the innovation of organizations, therefore, emphasizing the need for new frameworks and methodologies. Thus, addressing this gap requires combining insights from engineering, information systems and management science to foster a more agile, data-driven and integrated Project Management paradigm[42].

The proposed framework allows the structuring of the process of integrating Industry 4.0 technologies and tools into Project Management, from the identification of a certain improvement to its planning and implementation, including the implemented solution review, the evaluation from its integration and the consolidation of the approach.

In sum, the main aspects that justify the relevance and timeliness of this research are digital transformation, the change in Project Management practices, the need to improve organizational competitiveness and the challenges and new opportunities generated by technology. Industry 4.0 is part of a global digital transformation that affects all spheres of society, including how companies operate and deliver products and/or services [43].

It is essential to understand how the changes resulting from the adoption of new technologies affect Project Management, since companies are looking to become more efficient, agile and data-driven, which has direct implications for how projects are conceived, planned and executed [44]. An organization's ability to adapt to and leverage the benefits of Industry 4.0 can determine its competitiveness in the market [45].

The need to enhance workforce skills and ensure cybersecurity are just a few examples of challenges. Automation capabilities, advanced data analytics, and remote collaboration are aspects that also offer unique opportunities to improve project outcomes [46].

To achieve a high level of maturity in the implementation of Industry 4.0 technologies and its tools, it is necessary to reformulate the strategic plan, seeking the integration of all levels of the organization into the model proposed by Industry 4.0. Therefore, Project Management plays a fundamental role in this process, ensuring that technological initiatives align with organizational objectives [47].

6. Main Conclusions

The present study aimed to assess, through a SLR, the main impacts of Industry 4.0 technologies and its tools on the Project Management enhancement. A SLR was conducted to identify the most frequently applied Industry 4.0 technologies and its tools to evaluate their influence across distinct phases of Project Management.

The SLR revealed that case studies constituted the predominant research design among the selected publications. The construction sector emerged as one of the most extensively represented, a finding justified by the intrinsic complexity of construction projects, which often involve the coordination of multiple stakeholders, implementation of stringent schedules and the need to manage constrained budgets.

This sector has derived substantial benefit from the adoption of technologies such as BIM, IoT and Big Data, which collectively enhance efficiency, transparency and control of the decision-making process.

In terms of research contribution, 62% of the analysed studies (out of 34 documents) were classified as offering a high or medium level of relevance when addressing the impacts of Industry 4.0 integration in Project Management. Among the technologies identified, AI emerged as the most influential technology/tool, markedly in improving decision-making processes, which are inherently complex due to the multitude of variables affecting project outcomes.

The most frequently reported benefit of integrating Industry 4.0 technologies into Project Management was enhanced decision-making, enabling managers to adopt more informed, data-driven approaches and reducing dependence on empirical methods.

Based on the reviewed literature, a correlation matrix was developed, mapping specific technologies and its tools to their associated impacts and improvements, thereby providing a practical reference for researchers, practitioners and organisations. Furthermore, the study proposes the IPIREC-4PM, an Industry 4.0 and Project Management integration framework structured in six stages and grounded in the PDCA cycle. The model starts from the identification of intended improvements and the corresponding enabling technologies, by implementing planning, integration, performance review, pre- and post-implementation evaluation, and consolidation/ documentation of results for future reference.

Addressing the central research question: "*What are the principal impacts of Industry 4.0 technologies and its tools on the improvement of Project Management?*" the literature indicates a positive contribution, contingent on managers' ability to adapt both traditional and agile methodologies to emergent technological paradigms and to pursue continuous learning in their application. While the adoption of such technologies may present challenges, the foundational competencies of Project Management remain deeply rooted in human factors rather than technology alone.

The findings also indicate that the application of Industry 4.0 technologies to Project Management is still in its formative phase, necessitating further empirical investigation to enable effective integration. Advancing this research agenda has the potential to improve organisational performance in terms of scope, schedule, and cost, while better managing constraints throughout the planning, execution, monitoring, control, and closure phases of the project lifecycle.

As future work, it is proposed to assess the practical applicability of improvements arising from the implementation of Industry 4.0 technologies in Project Management, in accordance with the stages of the proposed IPIREC framework. It is recommended to undertake the mapping of organisations that currently employ, or have recently adopted, Industry 4.0 technologies and its tools to enhance outcomes related to the Project Management. Such mapping will enable the development of case studies not only to document the impacts and improvements achieved, but also the challenges encountered during the process of implementing these technologies and its tools within the domain of Project Management.

A further recommendation is to deepen the investigation into methods for improving the training of current and future managers and professionals engaged in Project Management. The objective is to integrate the use of Industry 4.0 technologies and its tools into undergraduate and postgraduate curricula, thereby instructing and equipping these professionals with the knowledge and skills required to apply such technologies and its tools effectively, to improve Project Management performance and organisational project outcomes.

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