Project Management as an Enabler of Industry 4.0: Insights from the Literature

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Abstract: This review aims to deepen the concept of Industry 4.0, highlighting its characteristics, key technologies, adoption barriers and benefits in terms of flexibility, productivity and competitiveness. As we move towards Industry 4.0, it is essential to understand the internal and external factors that affect the adoption of project management practices that provide a clear path towards its implementation, facing the challenge of remaining competitive in a constantly evolving technological environment.

[1] recognizes that there is no single strategy for adopting Industry 4.0 in SMEs, suggesting the need for approaches tailored to each company. The transition presents challenges related to scope, time and cost management, with effective management being crucial to facilitate organizational changes by controlling disruptions and adopting solutions for deviation control [2]; [3].

The literature review, complemented by a bibliometric analysis using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, ensures a structured documentation of relevant findings on project management and Industry 4.0. The results highlight the growing interest in the synergy between project management and Industry 4.0, approached from multidisciplinary perspectives. This attention is reflected in a wide range of publications and studies focused on this area of knowledge. Topics such as the redefinition of the role of project leaders in the face of digital transformation, key factors for the success of Industry 4.0 projects and their economic, social and labor impact, as well as the interactions between the business fabric and Industry 4.0 are clarified, identifying barriers and challenges.

Keywords: project management, industry 4.0, smart factory, digital transformation, Literature Review

La Gestión de Proyectos como facilitador de la Industria 4.0: Perspectivas desde la Literatura

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Resumen: Esta revisión tiene el objetivo de profundizar en el concepto de Industria 4.0, destacando sus características, tecnologías fundamentales, barreras de adopción y beneficios en flexibilidad, productividad y competitividad. Ante el avance hacia la Industria 4.0, es esencial entender los factores internos y externos que afectan la adopción de prácticas de gestión de proyectos que brinden un camino claro hacia su

implementación, frente al desafío de permanecer competitivos en un entorno tecnológico que evoluciona constantemente.

[1] reconoce que no existe una estrategia única para adoptar la Industria 4.0 en las PYMES, lo que sugiere la necesidad de enfoques adaptados a cada empresa. La transición presenta desafíos relacionados con la gestión de alcance, tiempo y costo, siendo crucial una gestión efectiva para facilitar cambios organizacionales controlando perturbaciones y adoptando soluciones para el control de desviaciones [2]; [3].

La revisión de la literatura, complementada con un análisis bibliométrico usando la metodología PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), garantiza una documentación estructurada de hallazgos relevantes sobre la gestión de proyectos y la Industria 4.0. Los resultados destacan el creciente interés en la sinergia entre la gestión de proyectos y la Industria 4.0, abordada desde perspectivas multidisciplinarias. Esta atención se refleja en una amplia gama de publicaciones y estudios enfocados en este ámbito del conocimiento. Se clarifican temas como la redefinición del rol de los líderes de proyectos ante la transformación digital, factores clave para el éxito de proyectos de Industria 4.0 y su impacto económico, social y laboral, así como las interacciones entre el tejido empresarial y la Industria 4.0, identificando barreras y retos

Palabras clave: gerencia de proyectos, **i**ndustria 4.0; fabrica inteligente; transformación digital; Revisión Literaria

Introduction

The industrial revolution, in its various phases, has witnessed profound and unprecedented transformations that have reshaped the global economy, business structures and the employment landscape. Today, in the era of the fourth industrial revolution, better known as "Industry 4.0", we are witnessing a new wave of disruptive transformations, driven by digitalization, artificial intelligence and robotics, among other advanced technologies [4]. The "Industry 4.0" initiative, launched by representatives from business, politics and academia [5], promoted digitalization and machine autonomy as an approach to strengthen the competitiveness of the German manufacturing industry.

There is a consensus that Industry 4.0 is short-lived, anticipating a coming industrial revolution driven by advances in biotechnology and nanotechnology. Artificial intelligence is expected to dominate the field of research and its applications are expected to expand globally in any domain requiring human intelligence, including managerial functions in companies [6]; [7]; [8]; [9]. [10] underscores the need to universalize access to these digital technologies and respond to the challenges of the COVID-19 pandemic with a productive digital transformation. This approach is particularly critical due to the low level of digitization in micro, small and medium-sized enterprises in the region.

SMEs, which are the backbone of many economies, especially in Colombia, are at the center of this wave of innovation and change. However, the adoption of these transformations varies significantly among companies. While some adapt quickly through the agile incorporation of innovations, others cling to traditional approaches, placing them in a vulnerable position in the face of the rapidly changing business landscape [11]. In addition to facing various challenges, SMEs in Colombia have the opportunity to benefit significantly from Industry 4.0, increasing productivity, improving efficiency and opening up to new market opportunities. These companies recognize the growing trend towards the adoption of advanced technologies and Industry 4.0 [12].

In this context, project management emerges as a fundamental discipline to guide the transition and capitalize on the opportunities offered by Industry 4.0 [13]. The ability to manage projects efficiently and adaptively, aligned with the demands of this new era, can make the difference between success and failure for many organizations, especially SMEs. During the literature review, we seek to identify and analyze various project management practices-including digital tools and technologies, adaptation of agile methodologies, and remote team management-to facilitate SMEs' transition to Industry 4.0. The importance of the growing strategic role of Industry 4.0 in project management has been evidenced in the optimization of time and costs and the increase of agility, thanks to the access to real-time information and the adaptability to changes and new business models.

The purpose of this comprehensive literature review is to establish a solid and comprehensive foundation that integrates the relevant concepts and paradigms on project management and Industry 4.0, approached from diverse perspectives and multidisciplinary approaches. Through a detailed literature review, it seeks to provide clarity on critical issues that will be developed in this article, including the distinctive characteristics of the fourth industrial revolution, the impact of Industry 4.0 on the economic, social and labor spheres, the barriers and challenges faced by SMEs in the face of this new paradigm, the demands of project leadership in the context of digital transformation, as well as a comparative analysis of project management practices, particularly the triple constraint and the other areas of project management relevant to the transition to Industry 4.0.

Methodology

The exhaustive and structured review of the existing literature provides a solid conceptual foundation for the research, with the objective of identifying gaps and potential areas of study in the Colombian context. To carry out this review, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology is used, recommended by [14] and [15] to transparently document the processes and findings of this type of research.

Following this methodology, specific inclusion criteria are defined to guarantee the relevance of the selected studies, such as publication within the last five years and in English or Spanish. These criteria are applied to the Scopus and Web of Science (WOS) databases relevant to the area of study. Exhaustive searches are performed using meticulously designed search strings aligned with the research questions.

From the main Scopus collection, 110 scientific articles are extracted, identifying 24 relevant keywords. The most prominent expressions in terms of frequency include: project management, Industry 4.0, construction industry, digital transformation, innovation, literature review, sustainable development and artificial intelligence. These frequencies are mainly concentrated in the years 2021 and 2022, periods spanning the pandemic and post-pandemic, where companies were faced with unprecedented challenges.

In the Web of Science (WOS) database, 32 keywords are identified within 73 featured articles. The most frequent expressions include: Industry 4.0, project management, performance, management, challenges, framework, future and innovation.

To ensure a systematic review, publications are evaluated at two levels: a preliminary review based on titles and abstracts, and a detailed full-text review of those selected in the first review. Finally, a detailed synthesis is made of the studies that passed both review stages and met the quality criteria, in order to build a solid foundation on the concepts, theories and paradigms relevant to project management and Industry 4.0.

Results

1. Definition of Industry 4.0 and its main features

Industry 4.0, the subject of study in both academic and industrial fields, is characterized by the integration and predominance of advanced technologies in its applications. Various authors have offered definitions that highlight this aspect**:**

- [16] define it as the technical integration of cyber-physical systems in manufacturing and logistics, employing the Internet of Things and Services in industrial processes.
- [17] assumes that the term "Industry 4.0" was coined at a trade fair in Hannover in 2011, where a German industrial plan called "Industrie 4.0" was announced. The plan was intended to encourage German companies to systematize production.
- [18] describe it as a transformation from automated factories to fully automated manufacturing environments, where processes are interconnected vertically and horizontally within business systems.
- [19] understand it as a combination of modern technologies and innovative business models that generate more customer value from collected data.

Despite the lack of consensus on a single definition, its association with the exploitation of real-time data and the digital transformation of manufacturing industry is highlighted. Industry 4.0 involves significant changes in organizations, societies and industries, improving performance and creating new value through digital technologies and information systems. The terms Industry 4.0 and digital transformation are often used interchangeably, especially in the context of digital transformation of manufacturing companies [3].

Authors such as [20] suggest that terms such as smart manufacturing, digital and Industry 4.0 are used interchangeably due to the lack of a universally accepted conceptual framework. [21] emphasize that the integration of production facilities, supply chains and service systems into value creation processes is the most crucial and unifying element of Industry 4.0.

[22] identifies key characteristics associated with Industry 4.0, including cost reduction, information transparency and reliability, decision making optimization, time efficiency, process simplification, among others. These characteristics reflect how Industry 4.0 can transform and improve business operations.

2. Economic, social and employment impact of Industry 4.0

Industry 4.0, characterized by an advanced integration of technologies such as robotics, artificial intelligence, and 3D printing, promises to transform society on multiple fronts. According to [23], this new era will not only reshape the economy and manufacturing, but also sectors such as education, law, and health, thanks to the massive implementation of sensors and the development of smart cities. The adoption of these advanced systems will enable more personalized production and efficient management, thus driving a more agile economy and sustainable economic development.

However, this technological revolution also presents significant challenges, including job losses due to automation and data security risks, which could increase the inequality gap. Despite these challenges, Industry 4.0 also offers job opportunities in new areas such as data analytics and cybersecurity, thus fostering a shift in the demand for skills. [24] and other authors suggest that the transition to a smart and ubiquitous society will depend on our ability to adapt these technological advances and harness their benefits in an equitable and secure manner.

In summary, Industry 4.0 marks a milestone in economic, social and labor transformation, catalyzing opportunities for innovation and growth while presenting critical challenges that require careful and adaptive management.

3. Role of project leaders in Industry 4.0.

The Fourth Industrial Revolution has significantly increased the number of projects and the importance of their management, requiring a flexible and adaptable "orchestration" approach. Projects in this era not only create innovative products and services, but the specialization of people working on projects requires them to acquire new competencies to be attractive to the organization, and the style of leadership will change, as there are no longer dependent employees, but "collaborators [25].

Leadership style has evolved, transforming employees into specialized collaborators. Leaders must now facilitate continuous collaboration and foster an environment of constantly updating competencies. Effective

human resource management and the development of technical and business skills are essential to meet the new challenges [26].

In summary, project leaders in Industry 4.0 must be adaptive facilitators capable of managing specialized teams and the complexity of the modern industrial environment. Continuous training and competency development ensure that they can guide their organizations towards a successful future.

4. Barriers and challenges of SMEs and Industry 4.0.

SMEs face several challenges in their transition to Industry 4.0, most notably data security, internal regulations, lack of aligned corporate culture, shortage of skilled labor, and confusion about standards and economic benefits of Industry 4.0. In Colombia, the focus on the short term and the technology gap exacerbate these challenges [19], [27], [28], [29].

There is no single strategy for adopting Industry 4.0, which implies the need for approaches tailored to each company. Research suggests that it is crucial to understand how the components of project success link to Industry 4.0 [1], [13], [30].

Project management plays a fundamental role, managing the triple constraint of scope, time and cost, to facilitate the adaptation of SMEs to this new era, minimizing disruptions and controlling deviations [2].

In conclusion, addressing these challenges with a strategic and adaptive approach is essential for SMEs to not only survive but thrive in the dynamic Industry 4.0 environment.

5. Adopting project management practices in Industry 4.0

Table 1 provides a clear view of how project management practices, particularly the triple constraint (scope, time and cost) and the other relevant project management areas, can be adapted by SMEs for their transition to Industry 4.0. Each entry in the table highlights conceptual positions and recommendations from the various authors that can facilitate the integration of SMEs into the dynamic Industry 4.0 environment.

Table 1. Authors' Perspectives

Author(s) /Year	Triple Constraint: Scope, Time, Cost	Other Project Management Areas	Contribution to the Transition of SMEs to Industry 4.0

[3]	Strategic alignment with Industry 4.0 objectives, including effective management of all project resources.	Focus on employee training, stakeholder management to facilitate digital transformation and continuous review of strategies, as well as effective communication management.	Provides a framework for strategic alignment, data security and effective leadership critical to the digital transformation of SMEs.
[1]	Selection of project leaders with multidisciplinary expertise to improve operational efficiency and good IT infrastructure.	Includes leadership, human resource management for technical competency development and training; effective communications to proactively manage risks. Stakeholder management for long-term strategies.	Promotes the adoption of Industry 4.0 technologies and adopt new business models through training and collaboration with external experts and Academia.
[26]	Details on the triple constraint not identified.	Emphasis on training in new technologies and methodologies to upgrade project manager competencies and project management maturity.	Train SMEs to effectively implement and manage Industry 4.0 components, addressing the challenges of digitization.
[31]	Flexibility and quality in project management to facilitate the implementation of Industry 4.0, with adequate planning to manage resources.	Leadership, cross-functional team building and training activities to improve human resources management.	Establish critical factors for the successful implementation of Industry 4.0, improving planning and adaptability.
[32]	Financing identified as crucial for project sustainability, directly related to costs.	Procurement management to ensure adequate financial resources.	Support the sustainability and economic viability of Industry 4.0 projects, crucial for SMEs in transition.
[33] [34]	The implementation of holistic strategies such as Lean allows to optimize processes and increase efficiency.	Use of Lean and agile principles to strengthen interpersonal competencies and improve productivity.	Promote more effective project management for the adaptability and sustainability of SMEs in Industry 4.0.

[35]	Focuses on matching the business environment with circular economy principles.	Focuses on implementing effective leadership and strengthened organizational culture. Stakeholder management for adaptive management strategies.	Promote a holistic approach to project management that integrates environmental and social considerations, vital for the adaptation and sustainability of SMEs in Industry 4.0.
[36]	Extension of the triple constraint to include social and environmental benefits, indicating holistic project management.	Includes risk management and sustainability as crucial components.	Promote project management that integrates technological innovations or advanced models in a sustainable way such as the "Project Management Technology Quotient" (PMTQ) and Green Project Management (GPM).

Source: Own elaboration.

This comparative table provides a synthesis of the aspects of project management that SMEs can implement to facilitate an effective transition to Industry 4.0. It highlights the importance of adopting an integrated management approach that extends the conventional triple constraint to incorporate additional dimensions such as human resource management, stakeholders, communications, risk, and procurement. In addition, it emphasizes the need to develop effective management strategies, organizational adaptability, and the adoption of innovative technologies, all crucial elements for successfully navigating the changing industrial landscape.

Conclusions

The article comprehensively reviews the literature on project management and Industry 4.0, highlighting how this technological revolution is transforming business structures, especially in SMEs. The main conclusions are then consolidated:

- Industry 4.0 represents a profound transformation in manufacturing and industrial processes through the integration of advanced technologies such as cyber-physical systems, the Internet of Things, Artificial Intelligence and full automation. Despite the diversity in definitions, there is consensus that Industry 4.0 involves the complete digitization and exploitation of real-time data to improve performance and create new value in industries. This change requires not only a re-evaluation of production processes, but also a redefinition of business models and organizational culture to take full advantage of these emerging technologies.

- The economic, social and labor impact of Industry 4.0 is significant, as it reshapes the global economy, manufacturing and other sectors such as education and healthcare. While the adoption of advanced technologies portends more personalized production and efficient management, it also presents major challenges such as job losses due to automation and data security risks. On the other hand, new

job opportunities are emerging in fields such as data analytics and cybersecurity, highlighting the need for continuous and equitable adaptation to these technological advances to ensure sustainable and fair development.

- The role of project leaders in Industry 4.0 is extremely important, as they must act as adaptive facilitators capable of managing specialized teams and the complexity of the modern industrial environment. This leadership requires effective human resource management, the development of technical and business skills, and continuous training to guide organizations towards a successful future. The transformation from employees to specialized collaborators demands a leadership approach that promotes collaboration and constant updating of competencies.

- Small and medium-sized enterprises (SMEs) face numerous challenges in their transition to Industry 4.0, including data security, internal regulations, and lack of aligned corporate culture. It is essential that SMEs adopt strategic and adaptive approaches to overcome these barriers, which can be achieved by implementing effective project management practices. Project management, which addresses the triple constraint of scope, time and cost, must be expanded to include other areas such as human resource management, stakeholder management, communications, risk and procurement. This will enable SMEs to not only adapt but thrive in the dynamic Industry 4.0 environment.

- Finally, Industry 4.0 marks an era of comprehensive transformation that requires strategic and adaptive management. Project leaders play a crucial role in this transition, ensuring that organizations can seize opportunities for innovation and growth while managing the inherent challenges. The integration of advanced technologies and complete digitization redefine manufacturing and other sectors, driving a more agile and sustainable economy. For SMEs to thrive in this new industrial landscape, it is crucial that they adopt integrated management approaches and develop effective strategies that include continuous learning and organizational adaptation.

These findings highlight the importance of project management as an essential strategic tool for SMEs in their transition to Industry 4.0, highlighting the need to address both technical and strategic challenges to make the most of the opportunities that the digital era offers.

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