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Original Article

Proposal of an Experimental Model for the Implementation of Industry 4.0: Exploratory Study in the Moroccan Context

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Abstract - *Organizations are encouraged to adopt smart technologies, such as Artificial Intelligence and the Internet of Things, due to the significant transformation represented by Industry 4.0. This revolution requires successful change management to embrace this transition. In this study, a literature review was conducted on the concept of change management and the various existing Industry 4.0 models. The methodology adopted is based on a focus group combined with a questionnaire addressed to Moroccan companies and structures. To ensure a smooth transition towards Industry 4.0, the goal was to create an optimal model that combines technological preparation with organizational and human adaptability. Analysis of the results highlights the central role of change management and a preliminary study of the existing situation, emphasizing that an integrated approach taking into account organizational, technological, and human dimensions is essential to guarantee successful implementation.*

Keywords - *Industry 4.0, Fourth revolution, Change management, Models, Focus group, Swot analysis.*

1. Introduction

The era known as Industry 4.0, or the fourth industrial revolution, involves digital technologies revolutionizing production methods and business models [1]. The integration and interconnection of systems, massive data collection, advanced automation, and artificial intelligence are the fundamental concepts behind it. By combining these components, it is possible to create production environments that are smart, flexible, and highly connected [2].

In this digital era, organizations are turning to Industry 4.0 to stay competitive and innovative. The benefits of this transition are significant: enhanced connectivity for closer collaboration, intelligent automation to reduce costs, and the capacity to offer customized products, meeting the growing demands of customers [3].

However, this transformation is accompanied by significant challenges. Companies are confronted with issues such as data protection, cybersecurity, employee training, and change management [4]. Implementing Industry 4.0 requires profound cultural and organizational adaptation. To ensure a smooth transition to the new paradigm, change management is crucial in combating resistance to change at various levels of the company [5]. In Industry 4.0, change management is not just limited to the introduction of advanced technologies; it involves a profound change in employees' perception, adaptation, and contribution to organizational change [6]. In particular, vertical, horizontal, and end-to-end change management is becoming imperative. In vertical change management, the involvement of leadership and effective communication are crucial, and senior executives must act as the main drivers of change [7]. At the same time, horizontal change management is becoming essential to coordinate efforts across the company’s different departments, overcoming traditional barriers to encourage greater cross-functional collaboration [8].

Finally, to maintain consistency across all organizational processes and along the value chain during transformation initiatives, end-to-end change management is vital [9]. In parallel, organizations are required to increase investment in employee training and skill development, while also implementing appropriate mechanisms to assess and monitor the effectiveness of change management efforts.

Morocco shares the same recognition as many other countries regarding the importance of implementing Industrial Revolution 4.0 to boost economic growth and improve global competitiveness [10]. Morocco recognizes the need to adapt the skills of its workforce, with training and awareness-raising programs underway to promote a smooth transition.

Numerous studies explore the technological aspects of Industry 4.0 or the general change management frameworks in developed economies. Few studies have explored change management in the implementation of Industry 4.0 in the Moroccan context. A comparison with existing models in developed countries, to highlight the specificity and original contribution of our model, has been conducted.

The main contribution lies in our dual critical and empirical approach. By offering an in-depth critical review of change management and existing models, highlighting their theoretical and practical limits. Then, by conducting a questionnaire based on a focus group study, among Moroccan companies, we could provide an empirical analysis of the specific factors that lead to the blocking (or resistance) of the transition to Industry 4.0 in Morocco, and formulate practical recommendations for industry companies to ensure a successful and less disruptive digital transformation, thus providing an essential factual basis for future research and industrial policy development.

The rest of this article is structured as follows: Section 2 presents in detail the principles, pillars, and models of Industry 4.0; Section 3 outlines the methodology adopted; Section 4 presents the data analysis and discussion; Section 5 offers a discussion of the proposed model, and Section 6 concludes.

2. Theoretical Background

2.1. Industry 4.0 and its pillars

The Fourth Industrial Revolution has become a focal point of interest among universities, research institutes, and organizations. This Revolution denotes the profound integration of digital advancements, fostering the rise of digital industrial technology, commonly called Industry 4.0 [11]

Before starting with organization 4.0, it is necessary to outline first a brief history of the concept of industry, which has had four revolutions until now [12]: The first industrial revolution arrived in the 18th century, as coal mining, steam-powered machines, and the first production machines rose. Over a century later, the second industrial revolution started in the 1870s-1890s, with electricity entering the everyday lives of people and the first assembly lines being developed. In the 1970s, the usage of the first information systems and technologies finally laid the basis of the third industrial revolution. Finally, at the beginning of the 21st century, the fourth industrial revolution started, called Industry 4.0. It is characterized by the development of robotics autonomy and the use of the Internet of Things and Artificial Intelligence.

In the Industry 4.0 era, interconnected computers, smart materials, and intelligent machines “talk” to each other, reach out to the real world, and eventually even make decisions with little or no human help, as digital connectedness and knowledge development. This revolution aims to create smart, connected factories that use real-time data to optimize production and maintenance [13]

Among the pillars of the fourth revolution, we can cite [14]:

2.1.1. Artificial Intelligence

It is a key component that can further enhance the capabilities and outcomes of Industry 4.0 initiatives. Its concept is that machines can be improved to demonstrate abilities commonly linked with human intelligence, such as learning, adjusting, and self-correcting.

2.1.2. IoT

It is a technological revolution that provides solutions for computations and analytics through cloud-based systems, thanks to a single device or a system of devices having network access and communication with information networks and the internet : [15]

2.1.3. Big Data

This technology manages a vast amount of data coming from sensors and computer systems, facilitating the extraction of pertinent information essential for prompt decision-making [16].

2.1.4. Autonomous Robots

Utilized in manufacturing to solve complex tasks that may be challenging for humans to accomplish easily [17]. Also, thanks to human-robot interfaces, the close cooperation between robots and human operators will be facilitated, providing the necessary information and instructions to industrial robots.

2.1.5. Simulation

Simulating real-world processes is a methodology that enables the development of a strategy for optimizing the envisioned virtual scenarios [18].

2.1.6. Cloud Computing

The integration of traditional client-server architectures into a unified digital environment is possible through cloud computing, which enables the virtualization of resources and services. It is generally structured around three main service models: Software as a Service (SaaS) is a service where users can access applications through subscription or purchase models, including Enterprise Resource Planning (ERP) systems. Users, particularly software developers, can create and deploy applications directly in the cloud through Platform as a Service (PaaS). Providing essential computing resources, including data storage and processing capacity, is what Infrastructure as a Service (IaaS) does, on the other hand.

2.1.7. Additive Manufacturing

Enables the production of customized components based on users' specific requirements, which is made possible by 3D printing. Not only does it apply to large-scale industrial applications, but it is also commonly used for rapid prototyping and the production of small or limited series.

2.1.8. Augmented Reality (AR)

AR is a technology that improves the interaction between humans and machines by superimposing digital elements on the real environment in real time. The use of AR leads to enhanced decision-making, training, and operational effectiveness by providing contextual information directly into the user's field of view [19].

2.1.9. Cybersecurity

In the digital age where cyber threats are prevalent, cybersecurity is a crucial aspect of modern business operations. It is about protecting computer systems, networks, and data against unauthorized access, cyber attacks, and data breaches.

Despite the persistent structural and organizational challenges, the adoption of advanced technologies within Moroccan industries is still progressing. The Industrial Sector has experienced a significant increase in turnover and value creation, which can be attributed to the ongoing digital transformation initiatives, as reflected in the 2024 Moroccan Industry Barometer published by the Ministry of Industry. [20]. In parallel, the 2021-2025 Industrial Relance Plan focuses on digitalization and the adoption of cutting-edge technologies such as the Internet of Things (IoT) to modernize the industrial sector.

2.2. Conceptual Foundations: Change Management

The transition to Industry 4.0 is often accompanied by the phrase 'change management' when reviewing previous work. In addition, there is a huge lack of empirical evidence to support change management theories and approaches, as [21] pointed out.

Change management is a structured approach to transitioning individuals, teams, and organizations from a current state to a desired future state [22]. It involves the process of planning, implementing, and monitoring changes in order to achieve organizational goals and objectives effectively. Otherwise, change management focuses on addressing the human side of change, including managing resistance, communication, training, and stakeholder engagement. It aims to minimize disruptions, maximize benefits, and ensure that changes are successfully adopted and integrated into the organization. Always, and according to [23], to succeed in the change process, three factors need to be taken into consideration:

2.2.1. Individuals

Employees and team members within the organization. The success of the change process requires their involvement, motivation, and ability to adapt to change.

2.2.2. Structure

The organization's structure is defined by the organization of roles, responsibilities, and processes within the enterprise, which includes hierarchical arrangements and coordination mechanisms that shape how activities are carried out.

2.2.3. Culture

Organizational culture is the collective values, beliefs, norms, and behaviors that make up the organization. Culture can influence how members of the organization perceive and accept change.

Besides, [24] discussed in his study the relation between the success or failure of a project and change management, and they found that leadership plays a significant role in determining the success of a project by ensuring that stakeholders are engaged, informed, and supportive of the project's objectives and outcomes. Also, [25] emphasizes the importance of change management in continually renewing an organization's direction, structure, and capabilities to meet the evolving needs of customers

In addition to the authors mentioned earlier, they contributed to the literature by offering diverse perspectives on change management, highlighting the need for evidence-based approaches, the challenges of continuous change, and the necessity of tailoring strategies to align with the specific organizational context. Other authors contributed valuable insights to the field of change management by offering practical frameworks, strategies, and models for organizations to navigate and implement successful change initiatives such as ; [26] explore strategic change and emphasize the need for organizations to adapt to the ever-changing business environment [27] that presents an eight-stage process for successful organizational transformation, focusing on mobilizing energy and commitment to identify and solve business problems.

In a business environment that is becoming more dynamic and competitive, an organization's ability to adapt to change has become a crucial factor in its long-term success. Like individuals, organizations must continuously adjust their practices and strategies to remain relevant and resilient. To adapt, top management must have effective leadership and clear communication, which is often called vertical management, as well as strong coordination and collaboration across departments and teams through horizontal management. Furthermore, a comprehensive end-to-end perspective is required, where processes are holistically examined from initiation to completion to ensure coherence, efficiency, and flexibility, as highlighted in previous studies [9]. By addressing change at these multiple levels, organizations are better positioned to manage uncertainty, stimulate innovation, and successfully implement Industry 4.0 initiatives. Recent research indicates that the success of digital transformation in emerging economies is influenced by the combination of technological progress and deep cultural adaptation within organizations [28]. Change management thus represents the main pillar of Industry 4.0 implementation.

2.3. Applied Foundations: Industry 4.0 Models

To stay aligned with anticipated changes, organizations must define an appropriate technology strategy in situations where they encounter uncertainty about future technological development. Industry 4.0 readiness models offer a structured method of assessing an organization's preparedness for Industry 4.0 technologies prior to implementation [29].

However, according to studies conducted on models, it has been observed that there are approximately four types: "roadmaps," "maturity models," "frameworks," and "readiness assessments".

Although the terms above may appear similar, there are slight differences in their definitions:

Roadmaps are strategic plans that align short and long-term objectives with precise technological strategies, aiding in their realization [30].

Maturity Models serve to guide individuals or organizations towards achieving enhanced maturity levels in various facets such as people/culture, processes/structures, and/or objects/technologies through a systematic and iterative improvement process [31].

Frameworks consist of organized sets of procedures, methodologies, and instruments utilized in the architectural process of a system. [32].

Readiness Assessments function as evaluative instruments used for analyzing and ascertaining the readiness level of conditions, attitudes, and resources across all system tiers necessary for the achievement of its objectives [33].

Table 1 summarizes the characteristics of about fourteen models identified in our study. Several features that were not addressed in previous studies have been included, such as recognizing the type of the study (Framework, model…), also the practicability of the model (feasibility, usability, and effectiveness in real-world applications within organizations), and its generality to be applied in different sectors, allowing for a more comprehensive comparison.

The analysis of these models reveals a series of gaps that have been recurrent across a set of about fourteen models examined.

Among the most frequently observed deficiencies is the lack of an action plan to address the weaknesses identified in the companies assessed [34]. The ability of models to provide concrete recommendations for improving business practices and performance is compromised by this deficiency. Another common weakness is the focus on large enterprises, to the detriment of Small and Medium-sized Enterprises (SMEs) [35-38]. This bias prevents the models from being generalized, as the challenges and resources available vary depending on the size and sector of the companies.

In addition, the use of specific frameworks, such as the SPICE [39], ANP [38], or ISA [40]. The framework may restrict the applicability of the models to specific industries or specific needs, thus excluding organizations operating outside these parameters.

Also, the fact of focusing on one domain and ignoring the others may limit the uses of the model, such as the IMPULS model [41], which is based on mechanical engineering or craft industries, as in the case of [42].

The comparative analysis revealed that most models lack adaptability to Small and Medium-sized Enterprises (SMEs), which represent the majority of industries.

Moreover, only a few frameworks provide actionable recommendations or validated field applications. These limitations justify the need for a new, context-based model integrating both technological readiness and change management dimensions.

3. Research Methodology

This paper proposes a model to guide organizations that aim to adopt Industry 4.0 initiatives and technologies, based on a review of the literature and a research approach.

This article explores a study that relies on insights gathered from a questionnaire. This survey is specifically for industrial companies in Morocco to understand how they embrace the 4.0 era, by learning from those that have already launched into the Industry 4.0 culture and helping those trying to engage in this new era.

The research was done in three steps:

3.1. First Step

Launching the process by conducting a literature review of" Industry 4.0" and "change management" terms and existing models to have an idea about their strengths and gap analysis.

3.2. Second Step

Based on the research done, and taking into consideration the importance of change management in the success of implementing I4.O initiatives, also recognizing the innovative nature of the topic and the need for a comprehensive examination, we chose to employ the focus group methodology first. This approach, initially devised and extensively utilized in medical and marketing research, has since gained credibility and widespread adoption within the field of social science research as well. This approach not only enabled us to gather ideas for refining our final questionnaire but, above all, to obtain valuable insights directly from the managers concerned. These insights enabled us to design a final survey that was much more relevant and aligned with the realities on the ground, thus guaranteeing relevant response proposals for our study.

3.3. Third Step

Dependent on managers' insights, the analysis of model gaps, as well as some interviews of the industry ministries since 2014, it was possible to create a questionnaire to distribute to the leaders of the other industries (see Figure 2).

To ensure representativeness, the participating companies were selected according to several criteria, including their industrial sector (automotive, aerospace, IT, logistics, and manufacturing), company size (small, medium, or large), and their level of technological maturity. The respondents were primarily senior managers and production or digital transformation leaders, ensuring a comprehensive understanding of both strategic and operational perspectives. The combination of the focus group and questionnaire approaches constitutes a mixed-methods design, allowing both qualitative insights and quantitative validation. The confidence level of 90% and margin of error of 5% confirm the statistical significance of the obtained sample (66 valid responses from 80 distributed questionnaires).

The methodology adopted is shown in Figure 1 below:

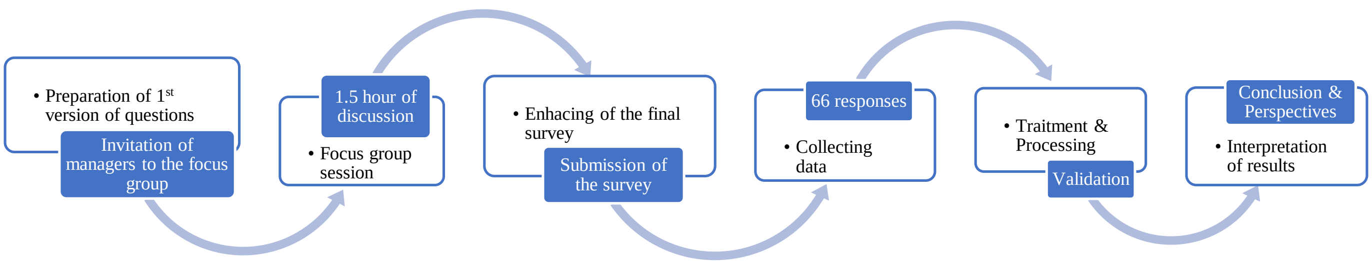

Fig. 1 The methodology followed

And the questionnaire structure is shown in Figure 2 below:

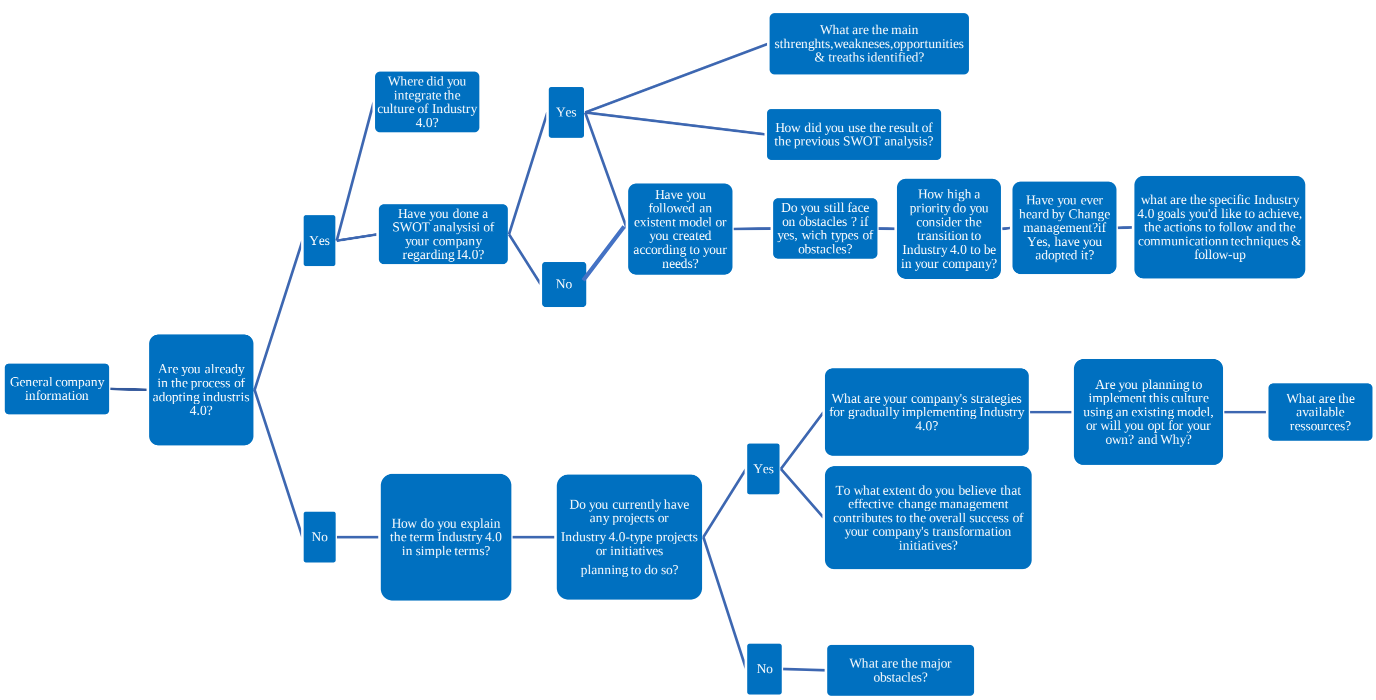

Fig. 2 Questionnaire structure

4. Analysis

4.1. Data Assessment

Our study focuses on analyzing the data collected from the conducted questionnaire. The study uses a mixed methods design to integrate insights from focus group discussions with data collected through a structured questionnaire, thus increasing the robustness of both qualitative and quantitative aspects of the study. The sample includes 66 valid responses from 80 industrial companies, representing various sectors such as automotive, aerospace, IT, and logistics. The participants were primarily managers who were responsible for production and digital transformation, which was chosen to capture perspectives from different organizational levels.

To verify the significance of our sample, we calculated the required sample size. Taking a total population of 80 companies, with a confidence level of 90% and a margin of error of 5%, a sample of 66.34 was required. Thus, the number of responses obtained (66) is very significant at the 90% confidence level, especially taking into account the adjustments made to eliminate redundant responses. These results allow us to guarantee that the data collected is representative and reliable for future analyses.

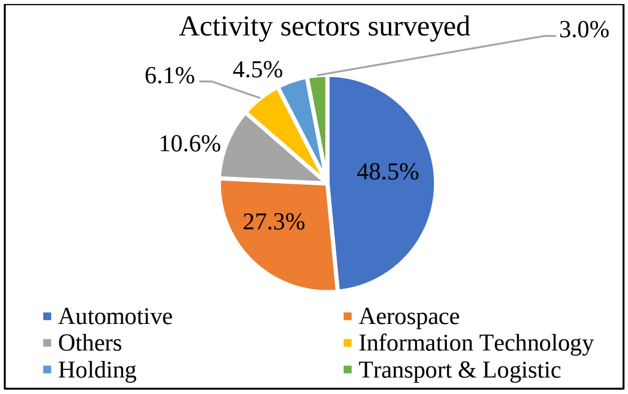

Fig. 3 Activity sectors surveyed

48.5% of the companies surveyed are in the automotive sector, 27.3% in aerospace, 6.1% are Information Technology societies, 4.5% in holding, 3.0% in Transport & Logistics, and the rest 10.6% in other sectors (mining, agrifood, PVC, consulting...).

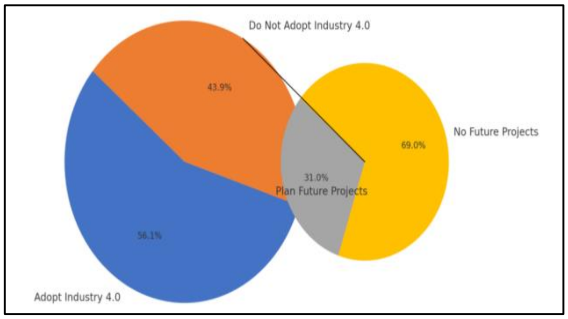

Fig. 4 Adopting industry 4.0

56.1% of the organizations interviewed are adopting Industry 4.0 initiatives, mainly in the production department (segment or production line), with a percentage of 67.6%,followed by the logistics 16.2%, co-design departments 10.8%, and the rest spread between the engineering department and at the level of the whole company (2.7%), while 43.9% of the sample either have future plans to adopt Industry 4.0, with a percentage of 31%, or do not see themselves in this revolution 69%.

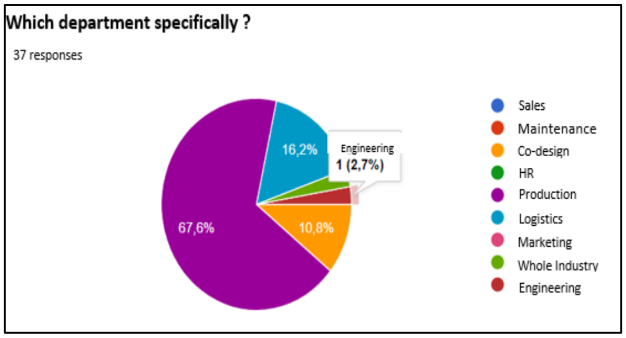

Fig. 5 Department in percentage

4.2. Data Analysis

In this section, we will analyze the relationships between the key variables in our study: the SWOT analysis, the type of model used, change management, and the appearance of obstacles by companies. To do this, we will use the Chi-square, p-value, and Cramer's V statistical tests. These tests will enable us to determine whether there are significant relationships between these variables.

4.2.1. Research Hypothesis

Hypothesis 1: There is a significant relationship between change management and the occurrence of blockages.

Null hypothesis (H0): There is no significant relationship between change management and the occurrence of blockages.

Alternative hypothesis (H1): There is a significant relationship between change management and the occurrence of blockages.

Hypothesis 2: There is a significant relationship between SWOT analysis and the occurrence of blockages.

Null Hypothesis (H0): There is no significant relationship between SWOT analysis and the occurrence of blockages.

Alternative hypothesis (H1): There is a significant relationship between the SWOT analysis and the occurrence of blockages.

Hypothesis 3: There is no significant relationship between the model followed and the occurrence of blockages.

Null hypothesis (H0): There is no significant relationship between the model followed and the occurrence of barriers.

Alternative hypothesis (H1): There is a significant relationship between the model followed and the occurrence of blockages.

First of all, 43.2% of the companies launched in the fourth revolution carried out a SWOT analysis, 31.3% of them followed an existing model, and the rest followed their own models. While 56.8% of the innovative companies that did not carry out a SWOT analysis went straight to the application of their model, i.e., 52.4% of them followed their own model, while 47.6% followed an existing model. Just 45.9% of companies have gone through change management during their transitions, while just 54.1% of organizations that have launched into this revolution have already heard of change management.

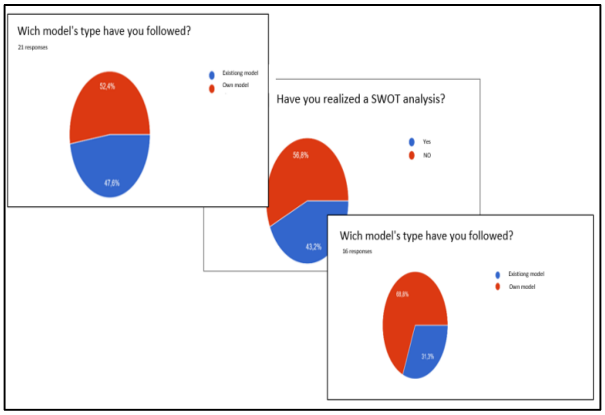

Fig. 6 The percentage of model types followed by societies that realized or did not realize SWOT analysis

So, the idea of the study is to find the key factor that causes blockages by answering 3 questions:

- Is there a link between the absence of a SWOT analysis and the occurrence of blockages?
- Is there a relationship between the appearance of blockages due to the lack of effective change management?
- Is there a connection between the type of model chosen and the occurrence of blockages?

In order to do so, and since the obtained qualitative data, we will proceed by logistic regression by introducing 3 variables: Chi-square, p-value, and V-Cramer in such a way that: If the p-value is less than 0.05, the null hypothesis (H0) is rejected in favor of the alternative hypothesis (H1). A higher Chi-square value indicates a greater probability that the relationship between the variables is significant. However, while the Chi-square test indicates the presence of a relationship, it does not measure its strength. V-Cramer can be used to determine the strength of the relationship. This measure of association varies from 0 to 1.

4.2.2. Result Analysis

After collecting the data from various companies in such a way as to identify the observed and expected frequencies of the different combinations of variables, we will proceed by constructing contingency tables for each combination of variables.

Table 2. Extract of the DATA

SWOT	Model's type	Change Management	Blocages
Yes	Existing model	NO	NO
Yes	Own model	Yes	Yes
Yes	Own model	Yes	Yes
NO	Own model	NO	Yes
NO	Existing model	NO	Yes
NO	Existing model	NO	Yes

Table 2 indicates the presence of Analysis SWOT, Change Management, and the type of model followed, and finally, the apparent blockages of the companies implementing the Industry 4.0 surveyed.

Table 3. Contingency of Change Management /Blockages combination

	Blockages: Yes	Blockages: NO	TOTAL
Change Management: Yes	17	2	19
Change Management: NO	10	8	18
Total	27	10	37

Table 4. Contingency of SWOT/Blockages combination

	Blockages: Yes	Blockages: NO	TOTAL
SWOT: Yes	15	1	16
SWOT: NO	12	9	21
Total	27	10	37

Table 5. Contingency of Followed model /Blockages combination

	Blockages: Yes	Blockages: NO	TOTAL
Existing Model	9	6	15
Own Model	18	4	22
Total	27	10	37

To understand the processing, the example of the relation: Change Management/Blockages will explain the fact:

For each contingency table, the expected frequency for a given cell is calculated using:

$$\text{Eij} = \frac{(row\ total)i*(colomn\ total)j}{N}$$

Where N is the total sample, here N=37.

Example – Change Management (detailed calculations):

- Total sample size: N=37
- Row totals: R1 = 19, R2 = 18
- Column totals: C1 = 27, C2 = 10

Digit-by-digit computations:

$$E_{11} = \frac{19\ X\ 27}{37} \backsimeq 13.86$$

$E_{12} = \frac{19 X 10}{37} \backsimeq 5.14$

$E_{21} = \frac{18 X 27}{37} \backsimeq 13.86$

$E_{22} = \frac{18 X 10}{37} \backsimeq 5.14$

The rest of the observed values and deviations are summarized in Table 6 below:

Table 6. Chi-square (χ²) calculation for Change Management/Blockages combination

Condition	Observed Value	Expected Value	Deviation (O - E)	(Deviation)^2	(Deviation)^2 / E
CHgYes/Blockages Yes	17	13.86	-3.14	9.86	0.71
CHg Yes/ Blockages No	2	5.14	-3.14	9.86	1.92
CHg No/ Blockages Yes	10	13.14	3.14	9.86	0.75
CHg No/ Blockages No	8	4.86	3.14	9.86	2.03

- $\chi^2 = \sum\frac{(Oij-Eij)2}{Eij}$
- $\chi^2 = 0.71+1.92+0.75+2.03 = 5.41$

P-value Calculation for Change Management/Blockages Combination

To determine the p-value associated with the chi-square statistic (χ2), it is necessary to know the number of degrees of freedom (Df) in the test. The number of degrees of freedom for a chi-square test in a contingency table is calculated as follows:

Df = (number of rows-1)×(number of columns) [47]
Df = (2-1)×(2-1)=1

For a value of χ2=6.90 with 1 degree of freedom, the p-value is quite low. By consulting a chi-square table, the p-value is approximately:

- $p \approx 0.025 < 0.05$

This indicates that H1 cannot be ignored; This suggests that there is a statistically significant relationship between the presence of change management and the presence of blockages (Yes vs. No); there is a very low probability that the observed differences between the expected and observed values are due to chance.

V-Cramer Calculation for Change Management/Blockages Combination

$$V = \sqrt{\frac{\chi2}{n*\min(k-1,r-1)}}$$

- χ2: The value of the chi-squared statistic obtained from the test.
- n: The total number of observations (the sum of all frequencies in the contingency table).
- k: The number of columns in the contingency table.
- r: The number of rows in the contingency table.
- Min (k−1,r−1): The smallest number of degrees of liberty among the rows and columns.

$$V=\sqrt{\frac{5.41}{37*1}} \approx 0.38$$

This means that there is a moderate to strong relationship between change management and blockages, validating the hypothesis that companies that have not gone through change management are associated with a higher frequency of blockages.

By coding the program using Python for the other relationships, the following results have been obtained:

```
=== Change Management vs Blockages ===
Chi-Square-Pearson: 5.39
P-value: 0.02023
V-Cramer: 0.38
Expected Frequencies:
[[13.86486486  5.13513514]
 [13.13513514  4.86486486]]

=== SWOT vs Blockages ===
Chi-Square-Pearson: 6.17
P-value: 0.01299
V-Cramer: 0.41
Expected Frequencies:
[[11.67567568  4.32432432]
 [15.32432432  5.67567568]]

=== Model Type vs Blockages ===
Chi-Square-Pearson: 2.15
P-value: 0.14232
V-Cramer: 0.24
Expected Frequencies:
[[10.94594595  4.05405405]
 [16.05405405  5.94594595]]
```

Fig. 7 Statistical results by combination

The results are summarized in the following figure:

```
Summary of Chi-Square Tests:
                               Chi-Square-Pearson   P-value  V-Cramer
Change Management vs Blockages           5.391726  0.020232  0.381736
SWOT vs Blockages                        6.170337  0.012991  0.408370
Model Type vs Blockages                  2.152727  0.142317  0.241209
```

Fig. 8 Statistical results summary

The figure above shows that "Change Management" and "SWOT" are significantly associated with blockages, suggesting they may have a potential impact on blockage management.

On the other hand, "Model Type" does not have a statistically significant effect on blockages, meaning that whether a company uses an existing model or its own model does not directly influence the presence of blockages. Since a strong association between the absence of change management and the occurrence of blockages has been found, as well as the absence of blockages due to the presence of SWOT analysis, whatever the type of model (existing or new), the proposal of a model integrating both has been made.

4.3. Discussion

The findings show that when change management and SWOT analysis are poorly structured, companies are far more likely to face implementation obstacles. Throughout the focus group discussions, many managers pointed to limited employee involvement and weak communication between departments as key challenges. As one production manager put it, “When we introduced automated systems, operators felt uncertain because the training came too late and the reasons behind the change were not clearly explained.” The ideas in [27], which emphasize the importance of leadership commitment and open communication in order to reduce resistance, are matched by these experiences. They also align with the study [6], which emphasizes that the human and organizational aspects of transformation often determine whether Industry 4.0 initiatives succeed or fail.

This study provides a striking example from one of the companies examined. The company made an effort to apply an Industry 4.0 framework that was taken directly from another site. However, this “copy-and-paste” approach did not deliver the expected results. The model did not accurately reflect the internal organization, available resources, and workplace culture of the company. As a result, productivity gains and process integration targets were not met. This finding validates the assertion made by [13] authors that Industry 4.0 frameworks need to be tailored to the specific socio-technical context of each organization, instead of being copied from foreign or pre-established models. The company case clearly illustrates that digital transformation cannot be separated from cultural and managerial realities.

The key to true success is not just selecting the right technologies but also aligning them with the organization's people, structure, and strategic vision. The analysis provides clear evidence that change management practices, SWOT preparation, and model structure affect the occurrence of implementation blockages, but these findings are primarily based on relationships. The evaluation of progress and impact is incomplete without the quantification of the transition through concrete Industry 4.0 performance indicators.

5. Proposed Model

The study of the existing situation and effective change management are the two key pillars crucial to the successful implementation of Industry 4.0, as revealed by in-depth analysis. An analysis of the existing situation provides a clear and detailed understanding of the systems, processes, and technologies currently in place. This step is crucial for identifying strengths and weaknesses, opportunities for improvement, and potential threats. By analyzing, companies can better align their digital transformation objectives with their operational realities.

Change management is also indispensable. The introduction of new technologies and working methods always leads to resistance and challenges. Effective change management ensures that employees and stakeholders are prepared and supported throughout the transformation process. This includes transparent communication, appropriate training, and ongoing support to ensure successful and sustainable adoption of innovations. With this in mind, the following approach to implement Industry 4.0 has been proposed:

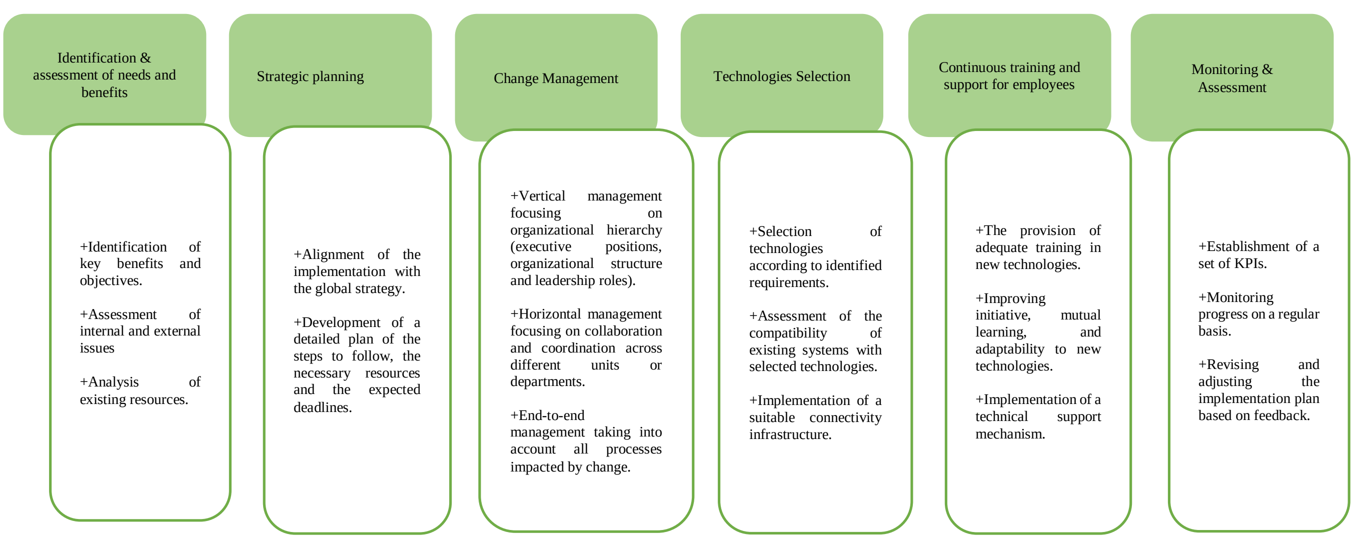

Fig. 9 Proposed Model

6. Conclusion

Change management and preliminary needs assessment are crucial to facilitate the transition towards Industry 4.0, while taking into account the specificities of the Moroccan industrial environment, as this research emphasizes. An optimized model was created to assist organizations during this transformation process through the use of a mixed-methods methodology that combines focus group discussions with a questionnaire survey after conducting an extensive literature review and a mixed-methods methodology.

The proposed model's contextualized and human-centered approach is largely responsible for the enhanced outcomes observed in this study when compared to existing frameworks presented in the literature. By incorporating structured change management practices, a situational analysis based on SWOT methodology, and an approach adapted to local organizational conditions, the model effectively responds to cultural, operational, and managerial challenges that are frequently insufficiently addressed in generic Industry 4.0 models. The close alignment between Moroccan industrial organizations' realities and the identification of potential constraints leads to more precise guidance for managing the transformation journey and more relevant guidance. In order to evaluate the robustness and practical applicability of the proposed model, an experimental validation phase is currently underway within an industrial structure. By using this practical deployment, we can refine our approach and gain empirical insights that can help us make actionable recommendations for a successful transition to Industry 4.0. The identification of technological requirements for implementation and the development of a comprehensive evaluation framework with measurable Key Performance Indicators (KPIs) will be a priority in future research. These elements will constitute the next stage in strengthening and operationalizing the proposed model.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Appendix

Table 1: Industry 4.0 Summary models

Model name	Research context	Dimensions	Maturity level	Type	Practical	General	Limits	Source
Impuls	The readiness of companies in the fields of mechanical and plant engineering for the Industrie 4.0 transformation	-Strategy and organization -Smart factory -Smart operations -Smart products -Data-driven services -Employees	Outsiders; Beginner; Intermediate; Experienced; Expert; Top performers)	Maturity Model	Yes	No, just mechanical engineering	*Limits of direct applicability to other industries. * Applicable just in terms of mechanical industries.	[44]
Maturity model for assessing Industry 4.0 readiness and the maturity of manufacturing enterprises	Index to calculate the readiness level of an SME	9 dimensions: Products, Customers, Operations, Technology, Strategy, Leadership, Governance, Culture, and People.	Calculate a maturity dimension within a factor and guess the maturity of 62 items.	Maturity Model	Yes	No,	An action plan is not provided to overcome the weaknesses of the enterprises being evaluated. Just addressed to firms that produce physical goods in-house with their own manufacturing machinery, and have a specific customer group (B2B or B2C).	[37]
A categorical framework of manufacturing for Industry 4.0 and beyond	The development of Industry 4.0 based on Cyber-Physical system attributes	4 dimensions: (a) factory, (b) business, (c) process, and (d) customers	5 levels : (1)single-station automated cells, (2)automated assembly system, (3)flexible manufacturing system, (4)computer-integrated manufacturing system, and (5)reconfigurable manufacturing system	Framework	No	No,	The roadmap paper caters more towards the needs of MNEs rather than SMEs.[critical] They may face challenges related to resource availability,	[38]

							organizational readiness, and technological capabilities.	
An overview of a smart manufacturing system readiness assessment	Assessing a factory's readiness to use Information and Communication Technology	4 dimensions: a) organizational maturity, b) IT maturity, c) Performance management maturity, d) Information connectivity maturity.	Maturity levels are determined within each dimension by scoring the maturity of activities within each dimension.	Readiness assessment	Yes	More oriented towards MNEs.	The simplification aids in structuring the assessment, but it may overlook other critical factors that influence smart manufacturing readiness. The rapid evolution of technology in the manufacturing sector may render the assessment model quickly outdated.	[47]
Three-stage maturity model in SME's towards Industry 4.0		3 stages : 1) vision 4.0 2) Enable, 3) Transform	Four Levels:1)Initial, 2) Managed, 3) Defined, 4) Transform, and 5) Detailed Business Model	Maturity Model	Yes pas encors	No, just in the Basque Country	Performing the self-assessment in the absence of clear instructions will not be an easy task, as the SMEs may lack the experience.	[39]
Development of an Assessment Model for Industry 4.0: Industry 4.0-MM	Proposed model for transitioning to Industry 4.0.	(1) asset management, (2) data governance, (3) application management, (4) process transformation, (5) organizational alignment.	(0) incomplete, (1) performed, (2) managed, (3) established, (4) predictable, and (5) optimizing.	Maturity Model	No	No	-Model based on SPICE, which may limit its applicability to organizations that operate outside the manufacturing	[42]

							domain or those with unique industry-requirements.	
Industry 4.0: building the digital enterprise	The digital transformation of industrial companies towards Industry 4.0.	(1) digital business models and customer access, (2) digitization of product and service, (3) digitization and integration of vertical and horizontal value chains, (4) data & analytics as core capability, (5) agile IT architecture, (6) compliance security, legal and tax, and (7) organization, employees and digital culture.	(1)Digital novice, (2) Vertical integrator, (3) Horizontal collaborator, and (4) Digital champion.	Maturity Model	No, all seven dimensions need digitalization	No	*Very difficult to find a supplier offering both cost-effectiveness and employing real-time update technology. *It is very costly, in fact, of all the dimensions that need digitalization.	[40]
Towards Industry 4.0: gap analysis between current automotive MES and industry standards using model-based requirement engineering	Building Industry 4.0 by analyzing the gap between automotive MES and ISA	3 phases : (1): Vendor selection phase (2): Requirement modeling phase (3): Gap analysis phase	Each phase has its own score, no level.	Maturity Model	Yes	Just to the industries that rely on MES systems	Not all automotive industries follow the ISA standard.	[43]
A smartness assessment framework for smart factories using the analytic network process	A framework that helps in understanding and applying the concept of smart factories.	Vision Goal Operations	(1) Checking (factory operates without external monitoring), (2)monitoring (factory gains the capability to collect and analyze data by installing external monitoring), (3) control (factory can identify and analyze abnormalities from the data), (4) optimization (factory is able to optimize its operations by	Framework	No, the requirement of significant resources in terms of time, expertise, and technology	Not universally applicable across all sectors	Subjectivity of judgement using expert opinion in ANP.	[41]

			interfacing with all its devices), and (5) autonomy (factory attains (2) the ability to enhance its self-sufficiency due to AI)					
Industrie 4.0 maturity index (managing the digital transformation of the companies)	maturity index to assess digital transformation	(1) Ressources (2) Organizational structure (3) Culture (4) Information Systems	6 maturity stages : (1) Computerization (2) Connectivity (3) Visibility (4) Transparency (5) Predictive Capacity (6) Adaptability	Maturity Model	Yes	Yes	The authors note that it is crucial to develop tools and best practices based on the model to assist companies in shaping their transformation concretely.	[48]
Maturity and readiness model for Industry 4.0 strategy		(1)smart products and services, (2)Smart business processes (3)strategy and organization	(0) **Absence**: The company fails to meet any of the prerequisites for Industry 4.0 (1) **Existence**: The company has initiated some pilot projects in its operational departments. (2) **Survival:** The company's products can manage real-time data and be tracked across various locations. (3) **Maturity:** The company's products are considered smart, and high-level data-driven services (4) are offered.	Maturity Model		No	limited application areas (smart finance, smart marketing, and human resources),	[49]
Towards a maturity model for Industrial Internet	Industrial Internet maturity	No dimensions but guidelines to follow: (1): Define scope: focus on the width/breadth of the model(generic/specific); covering all the departments or just the industry needs. (2) Audience: Address both	No further informations	Maturity Model	No	No	It does not cover all the aspects of the implementation of Industry 4.0.	[50]

		management-oriented and technology-oriented audiences. (3):Decision parameters (4): Design process (5): Application method (6): Respondents(stuff/business partners).						
SIMMI 4.0	Classifying the IT system landscape of companies in relation to Industry 4.0	(1)Horizontal integration (2)Vertical integration (3) Digital product development (4) Cross-sectional technology	(1) Basic digitization (2) Cross-departmental digitization (3) Horizontal and vertical digitalization (4) Full digitalization (5) Optimized full digitalization	Maturity Model	Not yet	Not yet	The model is still in its early stages and has not been fully evaluated or tested.	[51]
Design of self-assessment tools to measure Industry 4.0 readiness. A methodological approach for craftsmanship SMEs.	Assess the current state of Industry 4.0 readiness in SMEs within the craft industry.	(1) Production and operations (2) Digitalization (3) Ecosystem	Likert Scale from 1 (The company uses basic machines (laptop, fax, etc.)) to 5 (The company integrates the new technologies	Readiness Assessment	No	No	The study specifically targets Craftsmanship SMEs, which may limit the generalizability of the findings to SMEs in other industries or sectors.	[45]