Methodology for Digital Transformation: A Continuous Improvement Approach

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Abstract: Digital technologies have the potential to significantly transform the manufacturing industry by achieving improvements in productivity, quality and sustainability. Despite this, the uptake is relatively low as companies face a number of challenges in the implementation of digital technologies. There is therefore a need to support companies to develop and implement their Digital Transformation Strategy, with a clear business case. This paper proposes a methodology based on a quality improvement approach for Digital Transformation within manufacturing processes to better inform the business case. In particular, it provides an assessment and diagnostic to define a clear vision of the Digital Transformation Strategy, proposes digital solutions to start the implementation process with clear purposes and expected benefits, and measures the efficacy, efficiency and effectiveness of the digital solutions, all within a holistic perspective that should assure the sustained success of companies. To validate the methodology, preliminary results are presented of the assessment and diagnostic elements carried out in a global power solution manufacturing company. The focus areas selected were productivity, delivery performance, quality, and safety, in order to address problems and challenges reported by the company through their quality management system. Testing of usability in a real case provided useful output for company performance and valuable lessons to adjust the proposed methodology.

1. Introduction

Nowadays, the effects of globalisation are being faced by companies in the industry sector, where needs arising from suppliers, customers and the companies themselves are increasingly diverse and the required response time is almost immediate. They are living an accelerated transformation where techniques, tools, processes, skills and even systems recently adopted, do not necessarily guarantee the expected results in the immediate future. Consequently, companies are increasingly searching for alternatives to help them enhance their performance and achieve their planned objectives. Digital Transformation has emerged to provide the tools that could help to obtain a successful transformation. However, this transformation is not inherently smooth and straightforward to undertake, as numerous organizations are facing significant challenges to effectively implement digital initiatives. To overcome these obstacles, a continuous improvement approach is essential.

Principally, it has been observed that many companies lack a clear understanding of where to begin their journey towards implementing digital solutions. The complexity of these technologies can be overwhelming and the absence of a well-defined roadmap often leads to confusion. Therefore, many companies find themselves unable to harness the full potential of these technologies and their transformative capabilities.

Quality management is a cornerstone of successful business operations, and the introduction of Industry 4.0 technologies (digital solutions) has the potential to impact these practices significantly. However, companies often struggle to comprehend how these advanced technologies could enhance their quality management systems, streamline their processes, or innovate their products. This lack of awareness potentially hinders companies from leveraging the full benefits of digital solutions, thereby leaving substantial improvement opportunities untapped.

Finally, there is an increasing need for a tangible and quantifiable method to evaluate the impact of deploying the Digital Transformation journey. Without a standardised evaluation method, companies face challenges in assessing the benefits and drawbacks of the new technologies they implement. This lack of concrete, quantifiable data often makes it difficult for companies to define a strategy effectively and comprehend the return on their investment.

This paper presents a novel methodology that aims to provide a clear direction for companies embarking on their digital transformation journey, addressing different gaps identified in the prevailing knowledge and practice. This methodology is designed to address the existing gaps in Digital Transformation by guiding companies within a structured approach.

2. Background

2.1. The Fourth Industrial Revolution

The concept of Industry 4.0 has several meanings, depending on the author who defines it and the sense that is highlighted. For instance, it is referred to occasionally as the Next Industrial Revolution [4] or Industrie 4.0 [5], more frequently as Industrial Digitalisation [2] and the Digital Transformation of Manufacturing [6], but most often as the Fourth Industrial Revolution [7] or Industry 4.0 [8]. Additionally, there are several interpretations of this term, which can range from a simple explanation such as the incorporation of technology for the integration of processes [9], or the use of technologies in such a manner that the barriers between the physical and digital worlds disappear or are unnoticeable [10], to more sophisticated or technical descriptions. A recent study [11] analyses more than one hundred definitions, and concludes that they cannot be reduced to a single concept. Instead, it is important to be aware of the 'complexity and multidisciplinary nature of the phenomenon' [11] because it does not simply concern technological items, such as smart phones or electronic devices, but requires a deep understanding of the processes within the company environment and the context in which the new element will be implemented.

In discussing digital transformation, it is important to distinguish two concepts which have slightly different meanings: digitisation and digitalisation. Digitisation is the simplest approach to introducing technology into an activity, converting manual or physical tasks into digital formats, for example, a product catalog on a web page, in addition to the printed document. Digitalisation involves employing technology for a specific purpose, frequently to satisfy a need in terms of economic resources, such as decreasing expenses. On the other hand, digital transformation implies more than just a project or a group of projects; it is the effect that digitalisation produces throughout all facets of business to enhance its processes [1, 12]. Thus, for this research, the use of one or a combination of two or more enablers is considered a digital solution, because a complete analysis will be performed to solve the problem determined or achieve the objective established, with the use of all the tools or elements that might be required, not only the implementation of an isolated technology.

While digital technologies offer unprecedented opportunities for enhancing operational efficiency, facilitating real-time communication, and driving innovative problem-solving, their integration is not devoid of challenges. As example, some of the most frequent are the demand of new forms of operations to comply with customers' needs [13], the increasing complexity of the supply chain [14, 15], the need to be agile and adaptable to rapid changes in the business environment [13], and resistance to technological innovation' [14]. Since 2011, when this Fourth Revolution was expressed for the first time in Germany [16], considerable efforts have been made around the world to develop supportive theoretical frameworks that allow companies to exploit this emerging philosophy and to consider the implementation of digital solutions. For example, Hizam-Hanafiah et al (2020) generated an extensive literature review of readiness models for Industry 4.0 between the years 2000 and 2019. Through the analysis of 97 papers, they identified six principal elements or dimensions: 'technology, people, strategy, leadership, process and innovation'. The authors conclude that there is a lack of digital skills in companies that needs to be addressed, in order to improve their readiness for implementing technology in their activities and, as a result, their readiness for Industry 4.0.

The number of studies dedicated to theoretical frameworks went up noticeably in 2018 since, of the thirty different readiness models found by Hizam-Hanafiah et al (2020), twelve, or just under fifty percent, were developed in that year. Also, the number of models proposed by industry is notable: nine of the thirty models were proposed by companies such as Merz Consulting, MHP Porsche Company, Ronald Berger Consulting and PricewaterhouseCoopers, who promoted three models. However, despite all the research, there remain some issues to understand the foundations of Industry 4.0 [17].

The level of readiness and maturity for implementing digital solutions possessed by different countries with different economic and industrial conditions has a strong impact on the capability of companies to react and adopt such solutions. Castelo-Branco et al. (2019) evaluated to what extent two factors that represent Industry 4.0 were present across manufacturing industry in countries of the European Union: Industry 4.0 Infrastructure and Big Data Maturity. They concluded that the measurement in the level of perception was challenging because an observed absence of a clear definition of Industry 4.0 and the data utilised was not generated for this specific purpose since its origin. Also, they highlighted the importance of executing future research to discover the reasons for such difference amongst countries [18].

Diverse authors had conducted similar studies about tendencies, perceptions and, more topics relevant to Industry 4.0 around the world, and notwithstanding that probably they defined distinct purposes of research in their publications, the majority of their conclusions coincided at least in three points. The first one refers to the challenge it represents to be Industry 4.0 ready, as it requires extensive changes both in infrastructure and in the business model, amongst other aspects. The second point is that this movement was described as an important driver to impulse growth, improvement, and the potential of technical activity. Finally, the third point expressed the relevance of continuing more formal research, following a structured and homogeneous pattern, in order to obtain consistent and reliable results [2, 3, 16, 18].

2.2. Quality perspective

With the market constantly changing, companies have been forced to seek alternatives for managing and conducting their businesses, and the manufacturing field is no exception. Practices and methods of designing, planning, and executing processes are now different, even from the recent past, when it was sufficient to formalize the basic steps to assemble a product, and the clients had to adapt their needs in the best possible way. Now it is increasingly necessary to integrate multidisciplinary work teams to respond to new and ever more complex customer needs, combining engineering with organizational methodologies. With the emergence of new technologies and the concept of digital manufacturing, it is essential to adopt more collaborative processes and relationships with suppliers, employees and the customers themselves [19].

A systematic literature review recently conducted by Chiarini A. [20] discussed the relationships between Industry 4.0, quality management and total quality management, in order to identify common elements and understand how they are interrelated with an emerging Quality 4.0 concept. From approximately 75 papers reviewed, Chiarini concluded that four main topics are interesting for further research because they remain difficult to understand and apply. Two of them are centered in generating value for both the company and the customer, with the application of enablers such as big data, analytics, and cyber physical systems. The third topic is the relevance of acquiring the skills and developing a culture appropriate to this new era. The fourth is the importance of infrastructure, automation and data management for quality control and assurance.

Quality 4.0 is a term frequently associated with the application of technology to quality management, announced in the 2010s as the new quality revolution [21]. Quality 4.0 aims to enhance traditional quality methods through digital tools, influencing quality technology and consequently the processes and those who operate them. LNS Research proposed a model with 11 axes that includes a mixture of classical quality approaches such as quality

plans, audits, or the use of key performance indicators (KPIs), and new technological capabilities, for example big data analytics, blockchain and edge devices [22].

This new trend is attracting the attention of researchers, consultants, and commercial companies, who attempt to develop a theoretical framework to guide its implementation. To mention some academic examples in addition to LNS Research, Sony et al. (2020) identified technologies which they claimed to be digital tools that strengthen the ability to provide better products to customers [23], and Sisodia and Forero (2019) proposed a roadmap to initiate Quality 4.0 transformation [24]. On the commercial side, Plex Systems described some examples of how technology, especially sensors, supports the monitoring of productive activities, such as the start-up of machines and the fulfilment of product characteristics. They also highlighted how these technological systems support the incorporation of untrained personnel into manufacturing processes [25]. isoTracker Solutions has also offered a specialized software to work with electronic documents of a quality management system, in a cloud-based environment, as a beginning of the evolution to Industry 4.0 [26].

As Muhammad Asif claimed in his research paper, where some quality management models were compared with foundations of Industry 4.0, both philosophies have the common aims of enhancing quality, reaching, increasing or maintaining productivity, and facilitating flexibility across the value chain. However, the procedures and the tools they apply to achieve these objectives are completely different. Whereas quality management applies best practices to simplify and optimise processes, focusing on customer needs, on the other hand, Industry 4.0 increases the capability of operations integrating the newest, and sometimes, more advanced technologies, enhancing processes performance [27].

Quality management continues to be an interesting research topic since it has been transformed from traditional operations to the inclusion of digitalisation to accelerate the achievement of results [23]. However, there remain research gaps about how to include technology in processes, and particularly about the tangible benefits that companies will acquire in the short or medium term, from a practical point of view. For this reason, it is important to develop an evaluation method that should allow these companies to identify to what extent implementing digital solutions could contribute to quality improvement, in addition to enhancing their processes performance.

3. Research Methodology

The methodology employed to achieve this research comprises four phases, as shown in Fig. 1 the first three of which drew upon an extensive theoretical literature review to construct the Methodology for Digital Transformation, while the fourth phase involved an approach to certain companies to validate the methodology's applicability in an industrial setting.

For the selection of tools, information from the literature review was used to determine the appropriate techniques, tools or methodologies to address the subsequent phases. The selected tools and their application is described on the following phases. The literature review was also used to confirm and delimit the main purpose of this research.

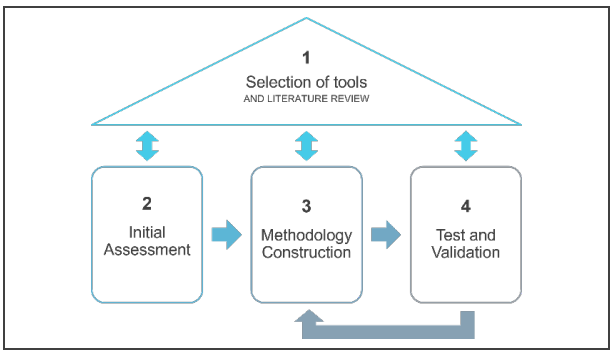

Fig. 1. *Research Methodology*

The initial assessment commenced in phase 2 was to identify all relevant enablers within the context of Industry 4.0. This endeavour employed a mind mapping approach to recognise whether a pattern was present applying digital solutions in quality management, however there was not enough evidence to determine the pattern. Consequently, it was relevant to continue investigating for information by other means, besides publications, and understand the context to select the enablers, or not, for improving processes. Subsequently, a meticulous analysis of approximately 30 models or solutions was conducted to assess their potential in addressing the challenges associated with the implementation of digital solutions. The analysis encompassed a number of elements proposed by academic authors, such as the competence [28] or eCRM [29] models, commercial consultants like the Maturity Model for Industry 4.0 - Enabling Digital Operations offered by PricewaterhouseCoopers through their webpage, and other methodologies or techniques already known or previously proved in different contexts, for example Business Process Management [30] or Lean Manufacturing [31]. The Interpretive Structural Modelling technique was employed to identify the relationships between challenges. This showed whether an element could positively or negatively influence the others.

Afterwards, an exploratory survey [32] was also conducted in order to comprehend the manufacturing environment in respect to the level of digitalisation that companies perceive as important nowadays, as well as their experience when implementing digital solutions. A questionnaire was developed with four sections including: concepts and expectations related with the importance of digitalisation for their company, approaches towards implementation critical factors for success when implementing digital solutions, usage of digital solutions, and general information about respondents to characterise the survey.

To construct the methodology in phase 3, the first step involved selecting the digital solutions that companies prefer to implement throughout their processes, focusing on those most relevant to their performance. This selection was determined through a thorough compilation and analysis of previous research efforts, exploring into the existing commercial alternatives, and incorporation of feedback from industrial people, as derived from the exploratory survey carried out. An examination of the reasons behind their decisions to adopt or reject these digital solutions was conducted, considering factors such as economic considerations, knowledge availability, time constraints,

among others. The second step encompassed defining the specific characteristics, parameters and metrics to be considered when constructing the Methodology for Digital Transformation,, determining how and when to collect the data, and selecting which digital solutions to include as part of the methodology. This information was valuable in identifying any existing limitations or restrictions, including potential sources of variation that could impact the application of the Methodology for Digital Transformation. To conclude phase 3, it was necessary to identify the methods and tools of quality and continuous improvement that would enable the construction of a robust methodology capable of supporting changes due to new projects or improvements in the manufacturing processes, assist in problem-solving and facilitate the decision-making process.

To complete phase 4, several companies were contacted to conduct in-situ testing of the Methodology for Digital Transformation. This was done to gather feedback regarding its practicality and likelihood of adoption, and to determine if it aligns with the intended purpose defined in the Introduction section. One company agreed to collaborate by testing the initial assessment as the first step and subsequently developing a case study with the obtained results. Once the testing and validation process is completed, throughout the practical application, valuable insights from the collaborating company will be obtained. Moreover, this will enrich the model by incorporating the industrial point of view gained during its implementation.

4. Results and Discussion

This section presents the outcomes and findings of the methodology employed for implementing a digital transformation strategy within the company. The methodology outlines the step-by-step approach taken to integrate digital technologies and processes into the organisation's existing framework. This may include the adoption of new software systems, automation of tasks, data analytics, and other digital initiatives to enhance operational efficiency and overall performance. It also describes the findings of applying the first stage of the Methodology for Digital transformation in a company, as a case study. In this stage, the company underwent a systematic evaluation of its existing processes, technological infrastructure, and organizational performance to embark on the digital transformation journey. Moreover, the assessment provided a clear understanding of the company's readiness to embrace digital solutions. The discussion explores the challenges encountered during this stage and how the proposed methodology was instrumental in guiding the company through this initial phase.

4.1. Methodology for Digital Transformation

The methodology for Digital Transformation is grounded in the Deming cycle (Plan-Do-Study-Act)[33-35], which is utilised to optimize business operations consistently and permanently. The depiction of this methodology can be found in Fig 2 and is characterized by:

a) Using ISO standards as a baseline across the methodology, for example for quality management systems fundamentals and vocabulary ISO9000 [36] and requirements ISO9001 [37], or Key performance indicators (KPIs) ISO 22400-1 [38] / 22400-2+A1 [39].
b) Taking advantage of actual manufacturing practices, particularly related to quality management.
c) Evaluating each stage of the cycle through historical data analysis, feasibility and risk assessment, among others.
d) Creating an enriched iterative cycle that would allow companies to conduct their strategy for digital transformation not only for a specific digital solution but for the medium and long term.
e) Having an interface between digital technologies and Quality Management to enhance performance.
f) Measuring quantitatively the benefits when implementing digital solutions through KPIs that reflect the digital solution's efficacy, effectiveness and efficiency, not just the success of the implementation plan.

4.1.1 Plan – Initial Assessment: To ensure a holistic overview of the manufacturing processes, the starting point of the methodology is the documentation resulting from the quality management system (context of the organisation, and performance and results of the processes), based on the seven fundamental principles of quality management, which support companies with the capability to effectively address the challenges posed by a markedly distinct contemporary business landscape. [36].

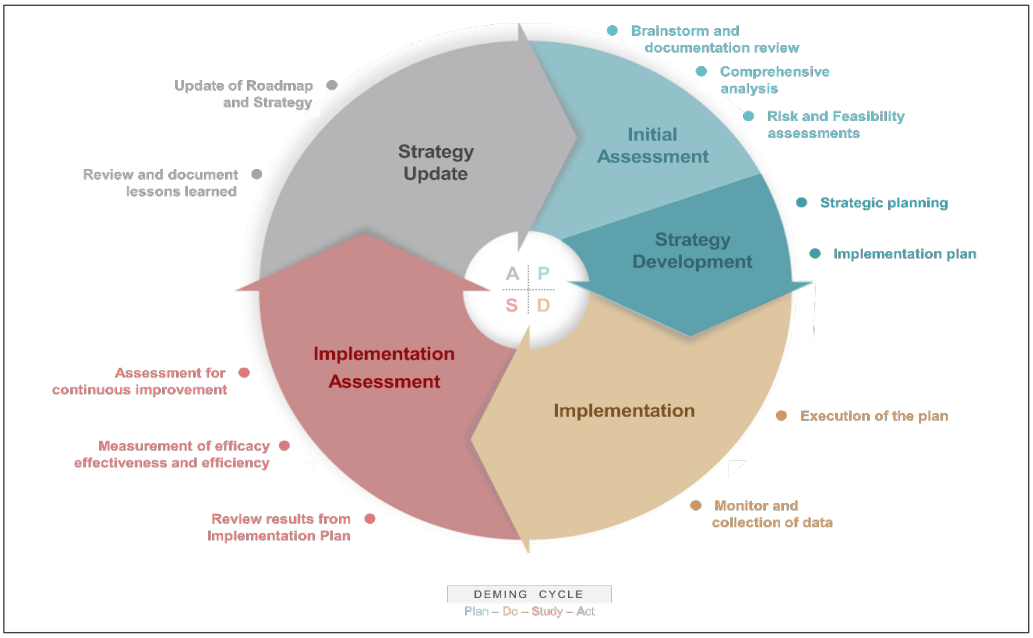

Fig. 2. *Methodology for Digital Transformation*

A checklist is used listing necessary basic documents and also documents that, while not always available, would ideally be consulted. The checklist defines essential information required to understand the knowhow demonstrated on the shop floor and the context within the company. If the company does not have a quality management system (QMS) or there is no documentation developed to execute the processes, the company can use some basic tools to describe its processes such as turtle diagram [40], SIPOC [41], Pareto chart [42], brainstorming [41], flow diagram [41, 43] or process map [42]. Once all documentation is collected or developed, the content of the documentation is reviewed with the aim of identifying reported problems, opportunities for improvement, or needs detected previously, whether on the shopfloor when executing the processes or as the result of a QMS activity. Then, to the list of all ideas identified as problems or opportunities, a level of importance or relevance is assigned to select a group of between 3 and 10 ideas to continue the analysis, which facilitates improved management and rigorous analysis of individual problems and opportunities. This activity can be executed with tools such as a nominal group technique to assure neutrality when selecting ideas [44]. With the list of problems and opportunities prioritised, a broad analysis is carried out using a Comprehensive Implementation Tool for Digital Transformation (CIT-DT), also developed as part of the proposed methodology, to understand relationships between elements in three dimensions (Fig. 3). The first dimension, Problem/Opportunity (P/O) versus KPIs, identifies which actual key performance indicators (KPI) can be affected by the P/O, either positive or negatively. The second dimension, KPIs versus ISO 9001 requirements for manufacturing processes, emphasises those requirements that will need to be modified if the KPI changes in its conceptual mode. The third dimension, P/O versus digital solutions or technologies, then identifies which solution could be ideally implemented to enhance the process or solve an identified problem. The result of this analysis is a list of the three most important P/Os with KPIs affected and possible digital solutions for implementation.

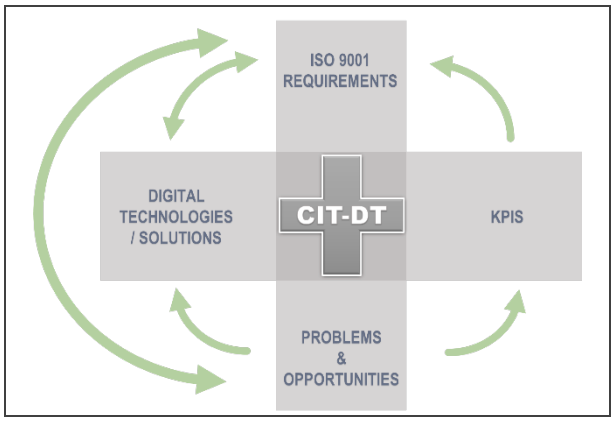

Fig. 3. *Elements of the Comprehensive Implementation Tool for Digital Transformation*

The last element of the initial assessment is the evaluation of feasibility and potential risks when implementing the proposed digital solutions. On the one hand it is necessary to define if the digital solution selected is feasible or if it can be implemented considering costs, performance of the process once it is functioning, production plans and projects, and constraints and limitations. On the other hand, using ISO 31000 [45] for risk assessment, ISO 27001 [46] and ISO 27005 [47] for information technology as guides allows threats and vulnerabilities to be identified to evaluate the probability of occurrence and potential consequences, as well as the magnitude of the consequences. After the digital solution is selected, it will be possible to define, with the same ISO guides, if the risks could be modified, retained, avoided, or shared within the process or with other interested parties, developing a risk management plan with the actions necessary to control the risks.

4.1.2 Plan – Strategy Development: The first step in Strategy Development uses the list of digital solutions identified or selected from the Initial Assessment Stage, and carries out a prioritization of the identified solutions. The main purpose is to solve current registered problems or to implement changes that might help to enhance the performance of the company, both previously identified as part of the quality management system activities. To do this, problem-solving tools such as the nominal group technique, Delphi method (where process or department managers are consulted as experts), or other consensus methods for group decision-making can be used. In this activity, other organizational elements should also be taken into consideration such as short- and medium-term market strategies, organisational changes in the company, introduction of new products, expansion plans, competitor behaviour (benchmarking), and long-term plans, among others. With the digital solutions prioritised, a roadmap for implementing them might be drafted. At this stage, it is necessary to focus on the benefits (digital transformation process) and to have selected at least one solution for implementation in the short term. For the digital solution chosen, it is also necessary to thoroughly analyse the problem that the digital solution might help to solve, declare the possible risks identified during the Initial Assessment Stage and ways to mitigate them, and describe the parameters and scope of the digital solution to be implemented, as well as the expected benefits to be gained. All this information will be required to construct the business case for the digital solution.

Subsequently, an extensive plan and the necessary actions are defined to carry out the selected digital solution, by either buying a commercial solution or developing the solution internally, with the help of suppliers or academic partners. The plan should include a measurement sub-plan, containing data to be collected and the metrics to be measured during and after implementation, in order to continue with the next stage of the methodology.

4.1.3 Do – Implementation: This is the shortest stage of the methodology but an important stage, since it involves executing the tasks previously defined when developing the Implementation Plan. Before executing the tasks, all people involved need to be informed about the plan, deadlines, milestones, and other relevant information about the implementation of the digital solution. Communication is a crucial factor for the success of every project or implementation to avoid resistance from people who do not fully understand the purpose of using a new digital solution or the general plan behind it. It is also important for operational people directly working on the shop floor who

do not participate on the planning and decision-making process, allowing any doubts or questions that might arise before the implementation to be solved.

On one hand, before starting the implementation and spending resources, a pilot study can be considered to test the digital solution selected and make adjustments to the original plan. The pilot study should consider a section of the process where the digital solution will be implemented. On the other hand, if a pilot study is not required, the implementation plan should be executed according to the tasks, goals, and milestones defined in the previous stage. This stage is mainly operational, as it follows step-by-step the activities stated in the implementation plan and does not require decision making. Therefore, it is very important to always observe the scope of the project, understanding where it begins and ends, avoiding any unplanned changes during execution. To guarantee the success of the project, the progress of implementation must be managed keeping in mind the metrics established for this purpose, either by monitoring the elapsed time in relation to the original plan or the accomplishment of milestones, among other examples.

4.1.4 Study – Implementation Assessment: Upon completion of the activities outlined in the Implementation Plan derived from the Strategy Development stage, a systematic evaluation of compliance is undertaken at predetermined intervals. To achieve this, it is essential to evaluate the alignment between the proposed implementation plan and the actual results achieved in a systematic and extensive manner. The review procedure requires a complete review of metrics, milestones, and qualitative evaluations, enabling a comprehensive understanding of the plan's effectiveness and adherence to the initial blueprint. In this context, it is important to emphasize that this review concerns exclusively to the implementation of the selected digital solution, form the Initial Assessment Stage, distinct from the execution of the Strategy for Digital Transformation or the Methodology for Digital Transformation itself.

Afterwards, the measurement of the efficacy, effectiveness and efficiency of the digital solution implemented should be conducted. This measurement is performed based on the KPISs identified during the Initial Assessment stage, by comparing the results before and after the implementation of the digital solution. To accomplish this, it is verified whether the digital solution:

a) demonstrates the achievement of its original intended results,
b) operates within the process, maximizing output while utilizing the allocated resources without unnecessary waste, and
c) works proficiently and accurately based on the comparison of the achieved results with the desired outcomes [36, 48, 49].

The assessment for continuous improvement is conducted following the ISO 9004 standard, to verify if the results obtained in short and medium-term contribute to the sustained success of the company by "consistently meeting the needs and expectations of [the company's] interested parties over the long term" [50].

4.1.5 Act – Strategy Update: After completing the Implementation Assessment stage, the experiences, whether they are successful or not, are documented regarding the execution of the Implementation Plan developed in the Strategy Development stage. These experiences, translated into lessons learned, represent the knowledge acquired throughout the process of implementing the digital solution and serve as a source of information for enhancing the execution of subsequent cycles in the Methodology for Digital Transformation.

Once the digital solution has demonstrated its ability to obtain the intended results for which it was originally designed, its impact on other activities or processes is verified. This impact can reveal in both positive aspects, such as energy conservation or task optimization, and negative aspects, for example through delays in the delivery of intermediate products resulting from the implementation of the digital solution, among other potential effects. Upon obtaining the results from the implementation of the digital solution and identifying any side effects or indirect benefits, the lessons learned should be documented for future reference and improvement.

The A stage of the Deming Cycle concludes with the update of the Strategy for Digital Transformation defined in the Strategy Development stage, based on the results obtained from the previous stage and the lessons learned documented. Actions are identified to ensure a consistent and successful continuity of the Strategy for Digital Transformation. These actions involve defining new activities, modifying the original strategy based on the initial assessment, or continuing with the original one. Records from the quality management system, such as non-conformances and internal audit reports generated during the implementation of the digital solution, along with all results from previous stages, are considered during the update as part of the second or following cycle of the Methodology for Digital Transformation.

4.2. Validation Study

To test the applicability of the Methodology for Digital Transformation and validate the proposed stages, Danfoss agreed to collaborate on the research project as an industrial case study. Danfoss is a multinational company established in Denmark, with operations in more than twenty countries and three main business segments: power solutions, climate solutions, and power electronics and drives. The company provides solutions that contribute to increasing productivity in machinery, decreasing emissions and energy consumption, and enabling electrification. In order to be closer to customers and increase their loyalty, Danfoss offers data, analytics and connectivity within their solutions in response to the digitalisation trend, allowing the customer to monitor tasks and optimize their activities [51].

The site participating in the case study is in the United Kingdom and provides power solutions. It was acquired from Eaton's hydraulics business in 2021 and became Danfoss Power Solutions, one of the most innovative companies in the world [52]. This is relevant in the application of the Methodology for Digital Transformation since, although the manufacturing processes and products have been retained from Eaton, the general operation, strategies, and vision of the company need to change to align with Danfoss. Accordingly, the results of the application of the methodology may provide key elements at a critical juncture for its digital transformation strategy in the medium or long term.

To begin the Initial Assessment, the first stage of the Methodology for Digital Transformation, it was necessary to collect data from their Quality Management System (QMS).

For this purpose, the records of the past five years were included for analysis, from 2018 to 2022. The main requirements from their customers encompass product quality and performance, on-time delivery, cost competitiveness, ease of doing business, and leading-edge technology development. For this reason, the main goal of the Initial Assessment was to focus on four main areas within their processes: productivity, delivery performance, quality internal, and safety, defined as core KPIs.

Following an extensive review of all records, including non-conformance reports, internal and external audits, management reviews, customer complaints, and corrective and preventive actions, among other records, a total of 70 problems and opportunities were discerned. These elements primarily concern to hoses, pumps and motors, valves, milling, and turning. The problems and opportunities exhibit correlation with the quality management system, regarding topics such as customer communication, documented information, requirements for product, and corrective actions.

The Comprehensive Implementation Tool for Digital Transformation, described in the previous section, was assessed through four problems and opportunities, which held special significance for the company. These issues were closely associated with the following aspects: the quality of the product evaluated in light of customer feedback (operational control), fulfilment of product specifications, requirements and standards (operational control/control of production), customer claims (customer satisfaction), and review and update of documentation (Documented information). As a result of applying the CIT-DT, nine different digital solutions were identified as alternative approaches to address the problems and opportunities selected. The most relevant are immersive technologies, monitoring tools, and automated inspection. These digital solutions were meticulously analysed to assess their applicability and characterise the specific use within the company. The analysis also aimed to identify potential risks associated with non-implementation and explore their implications and effects on the shopfloor and the processes. After conducting the Initial Assessment, Danfoss acquired the essential information to make an informed selection of the most suitable digital solution for implementation. Additionally, they have gathered pertinent information concerning the benefits, risks, and overall feasibility, which will be utilised to document a comprehensive business case.

5. Conclusions

This research has presented a comprehensive Methodology for Digital Transformation, based on the Deming Cycle for continuous improvement and underpinned by quality management methodologies and quality improvement tools, which companies already use to solve problems when performing the processes on the shop floor. By addressing the gaps outlined in the Introduction and providing clear steps to follow, it is suggested that companies could proactively adapt to new technologies, capitalise on emerging opportunities, and drive sustainable growth in the digital era.

In practical application, the methodology was tested during the first stage of the Initial Assessment at Danfoss. The results demonstrate that the methodology works as a structured guide to initiate the planning process for a Digital Transformation Strategy. The availability of historical records from the quality management system expedited the analysis and identification of alternatives for the implementation of digital solutions.

Finally, further testing of the remaining three stages will be essential to fully validate the proposed methodology. This can be accomplished either through continuing the following stages after the Initial Assessment stage with Danfoss or conducting tests with other companies of different sizes and sectors. By undertaking such validation efforts, the functionality and applicability of the proposed methodology can be robustly verified across diverse organizational contexts.

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