I4.0 assessment and roadmap: a case study in a medium-sized company in the consumer goods sector

Avaliação e roteiro da I4.0: um estudo de caso em uma empresa de médio porte do setor de bens de consumo

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ABSTRACT
The aim of this research is to define a maturity assessment model for SMEs and apply it to a company in the consumer goods sector, as well as to outline an I4.0 implementation roadmap considering the company's business strategies. The literature shows that there is a lack of studies focusing on applying maturity assessment models in SMEs, as they are more adherent to the large corporation scenario. Thus, this research assesses the developed maturity models and selects the one that can best be applied to the case study. Through a search in the main literature databases, we listed the main maturity models that can be applied in SMEs. Through an assessment of models and guidelines from other research, we selected the IMPULS maturity model for this case study. After applying the maturity model, the company studied was classified at maturity level 1, that is, the company is considered a beginner. Thus, focusing on the next 3 years of work, a roadmap was designed focusing on the 3 main dimensions with gaps in the assessment.

Keywords: maturity model, industry 4.0, small and medium enterprises (SMEs).

RESUMO
O objetivo desta pesquisa é definir um modelo de avaliação de maturidade para PMEs e aplicá-lo a uma empresa do setor de bens de consumo, bem como delinear um roteiro de implementação da I4.0 considerando as estratégias de negócios da empresa. A literatura mostra que há uma carência de estudos voltados para a aplicação de modelos de avaliação
de maturidade em PMEs, pois eles são mais aderentes ao cenário das grandes corporações. Assim, esta pesquisa avalia os modelos de maturidade desenvolvidos e seleciona aquele que melhor pode ser aplicado ao estudo de caso. Por meio de uma pesquisa nas principais bases de dados da literatura, listamos os principais modelos de maturidade que podem ser aplicados em PMEs. Por meio de uma avaliação de modelos e diretrizes de outras pesquisas, selecionamos o modelo de maturidade IMPULS para este estudo de caso. Após a aplicação do modelo de maturidade, a empresa estudada foi classificada no nível de maturidade 1, ou seja, a empresa é considerada iniciante. Assim, com foco nos próximos 3 anos de trabalho, foi elaborado um roadmap com foco nas 3 principais dimensões com gaps na avaliação.

**Palavras-chave:** modelo de maturidade, indústria 4.0, pequenas e médias empresas (PMEs).

### 1 INTRODUCTION

Digital transformation and the 4.0 movement have been posing important challenges for Industrial Management, which needs to adapt its internal processes to promote faster responses and controlled costs to maintain competition in this new scenario.

The term Industry 4.0 (I4.0) was coined in Germany in the year 2011 and is related to the vertical and horizontal integration of the value chain, where people, objects, equipment, and other resources need to be connected, thus providing agility, flexibility, autonomy, and responding in a rapid manner to the demands of an intensely dynamic environment [1]. [2] comments that the term I4.0 can be defined as the integration of information and communication technology into industrial manufacturing. The technical integration of cyber-physical systems (CPS) can be considered the essence of I4.0, as well as the use of the Internet of Things in industrial processes [3]. Another common new age term is Smart Manufacturing (SM), which refers to the integrated systems of a factory, which make the whole system more flexible and customized [4].

To achieve a successful implementation of the fourth Industrial Revolution and overcome the pressure on technological advances, companies will need to review their growth strategies and priorities [5]. However, before investing in new digital technologies, companies need to understand their starting situation and their organizacional needs [6]. [7] state that, for all types of companies, large or small and medium enterprises (SMEs), it is essential to know the tools and paths necessary to overcome the challenge of I4.0. It is noticeable that many manufacturing companies still face the challenge of implementing SM concepts. According to [8], and [1], some
entrepreneurs still do not have a clear vision about the current trend of industrial digitization, and some leaders still do not know how to implement it.

Considering the initial challenges, maturity assessments stand out as an integral tool for manufacturing companies, especially SMEs [9], as SMEs have more difficulty in extracting the full potential of I4.0. A good and structured maturity model enables the initialization of the digital development process and helps to decrease uncertainties and risks about the technologies to invest in [10]. [8] state that there is no commonly accepted standard model or methodology for measuring I4.0 maturity in companies. Maturity models can be used to guide SMEs to move in the right direction and reach maturity. A proper transformation plan as well as measuring its maturity index are essential to ensure a stepwise transition and to achieve a complete and successful transformation [9].

There are assessment tools called maturity models that evaluate whether a company can be considered a participant in I4.0 and to what extent it is involved in it. The models have dimensions that define what level of maturity the company is at and what its next stage of evolution should be [11]. Considering the characteristics and limitations of SMEs, we realize the importance of measuring their level of readiness/maturity regarding I4.0 in order to be assertive in directing actions and prioritizing investments.

In this context, considering I4.0 as the deployment of technologies, it is noticeable that larger companies are further along in the implementation of I4.0 than SMEs [12]. However, often due to a lack of skilled people or a more cautious attitude due to technologies not yet known, SMEs are not yet prepared for the structural changes that the fourth revolution will entail [13].

According to [14], the main barriers/obstacles to implementing Industry 4.0 in SMEs are related to the skill set of people, that is, skilled labor, and economic analysis/benefits that can be achieved from the use of new technologies. In light of competitiveness, this scenario needs to change, and SMEs will move forward and learn quickly to appreciate and implement emerging technologies and digital practices [9].

[15] comment, in their study, that there are still few studies related to I4.0 application and concepts in SMEs. While there are studies already available on maturity models, including organizational, business, and technological aspects, most may only marginally support SMEs in adopting SM and Industry 4.0 [16]. We know that SMEs need to know how to stand out in growing markets. These companies find it difficult to know where to start to generate new growth opportunities or do not know how to face the
challenge towards Industry 4.0 and how to consider Industry 4.0 paradigms in their business [17].

In this matter, the objective of this research is threefold:

• To determine the I4.0 readiness/maturity assessment model for SMEs;
• To apply a maturity assessment model in a medium-sized company in the consumer goods industry.
• To define an implementation roadmap of I4.0 concepts for a medium-sized company in the consumer goods sector.

This paper is structured as follows. Section 2 presents the methodology used in this research. Section 3 discusses the framework models in the literature and the choice of the model applied in the company studied. The results of the application of the framework are in section 4. Section 5 contains the practical and managerial implications, and finally, this section comments on the conclusions of the study.

2 METHODOLOGY

2.1 RESEARCH PROCEDURES

In this study, there are 3 research steps. The first is characterized as a bibliographic research, in which we conduct a search on the main databases Scopus and Web of Science on the topic of maturity and readiness models in I4.0, and a second, more detailed search to understand these models applied to SMEs. In step 2 of this study, we will define the framework model to measure the maturity/readiness level of the company studied in relation to the concepts and application of I4.0. During this step, we will also apply the assessment form through an interview with the company's managers/experts. As a final step, we will evaluate the results of the assessment form to define in which stage of I4.0 implementation the company is, and, based on this, draw a Roadmap aligned with the company's strategic objectives for the coming years regarding digitalization. Figure 1 details the steps of the research.
2.2 COMPANY PRESENTATION

This study was carried out in a medium-sized consumer goods company, with a commercial presence all over the Brazilian territory, with more than 50 years of experience. Its portfolio comprises more than 300 products in the commercialization phase, with approximately 20% annual renewal of the product portfolio. The products are marketed through a multi-channel structure, with very distinct buying patterns and service level requirements. In terms of lead times, the longest cycle is product development, which can take up to 12 months, and there is a high incidence of imported raw materials, with lead times agreed upon by suppliers that can reach 120 days. The industrial structure is quite vertical, with several operational structures within an industrial park located in the southern region of Brazil, where the shipping of orders is also centralized. Currently, the company does not have an automatic industrial data collection system and depends on the operators for information about performance and operational quality. Thus, all project and work directions are based on a combination of collected but uncertain data, and production management experience.

3 FRAMEWORKS FOR INDUSTRY 4.0 AND APPLICATION

3.1 MODELS PROPOSED IN THE LITERATURE

The implementation of I4.0 concepts can be considered a complex transformation, which does not occur quickly. As prerequisites, it requires analysis, modifications, investments not only in strategy and technology, but also in social [18]. In the search for greater assertiveness and results from digital transformation, it is important for companies to have a clear vision about the environment that will be transformed, the types of products, the company's vision and mission, employee involvement, and business
strategy. According to [18], many managers are aware that they need to be prepared for the fourth industrial revolution, but it is difficult to measure the distance from the current situation to the desired future state. For these authors, some questions may arise during this process, such as:

- Is our company ready for this transformation?
- What are the impacts of measurement systems on the company's competitiveness and strategy?
- What is the ideal method to measure the maturity of the company in such a way as to allow for evolution?

The application of a maturity model can serve as a guide to help SMEs achieve maturity in its explicit sphere and help them move in the right direction [9]. The maturity model shows a trend, and each model has its own forms, dimensions, and criteria. Thus, the literature already has some widespread models, showing what should be the starting point of the company and the roadmap to guide strategic decision-making [19].

It is essential to understand that each company has its own strategies and end goals [20]. For [21] and [22], in general, reaching a high maturity level is not always the best for a given company. Within this context, [20] claim that a thorough analysis of the dimensions of Industry 4.0 is required, including the business objectives, the size of the company, its target market, and its strategy. Only after the overall maturity level is accurately assessed should the company start thinking about the goals for each area or department [23]. There are several maturity models related to I4.0, based on the literature; the selection of the models presented in Table 1 is based on the research conducted by [14].

According to [14], the models have distinct characteristics: while some focus on the technology used in manufacturing or the product itself, others focus on assessing the changes that are achieved by using the technologies. The seven models presented in table 1 cover the main themes related to I4.0 but use different approaches.

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Author</th>
<th>Year of Publication</th>
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<td>Framework for Assessing Manufacturing SMEs Industry 4.0 Maturity</td>
<td>[14].</td>
<td>2021</td>
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3.2 CHOICE AND APPLICATION OF THE MODEL

According to the three steps of the research, in the first step, we conducted a search in the main research databases to assess the current I4.0 maturity models available. We assessed twelve maturity models, by understanding which dimensions each one assessed, and the company's classification levels. In the second step, we defined the model to apply in the company. Since SMEs are at early levels of maturity with respect to I4.0, we can observe that the current assessment models are not ideal for these companies [31]. In their study, [14] stated that the literature still lacks a more focused and detailed approach to the characteristics of SMEs to measure more accurately the maturity level of these organizations.

Thus, due to the ease of access to the maturity assessment form, we decided to follow the proposed IMPULS model. For [14] the IMPULS maturity model is one of the most cited in the literature and presents a set of barriers that companies need to overcome to start the 4.0 journey and provides guidelines on how to achieve the next maturity levels. The IMPULS model can be considered the most comprehensive and incisive in the literature [3], and the most transparent and detailed, according to [32].
The IMPULS Readiness Model, developed by Lichtblau et al. (2015) classifies companies into 6 levels with respect to the adoption and application of I4.0 concepts:

- Level 0: Outsider
- Level 1: Beginner
- Level 2: Intermediate
- Level 3: Experienced
- Level 4: Expert
- Level 5: Top performer

The model is based on six dimensions: Smart Manufacturing, Smart Products, Data-driven services and Smart Operations, Strategy and Organization, and Employees. Considering the six dimensions, we developed a questionnaire that considers the following aspects: structural attributes of companies, general questions about Industry 4.0, degree to which companies comply with the dimensions of Industry 4.0, motivators, and barriers to roadmap 4.0 [30].

After choosing the I4.0 assessment model, a multidisciplinary company team was defined to answer the IMPULS questionnaire, to allow a view of the company's different departments and ensure greater assertiveness and transparency in the answers. The assessment team included: CEO, Production Manager, Sales Manager, R&D Coordinator, Purchasing Coordinator, IT Specialist, and Production Management Consultant. The form was answered in an online format, and the questions were classified according to each of the 6 dimensions of the model.

4 RESULTS AND DISCUSSION

The company studied reached level 1 in the model proposed by [30], as presented in figure 4, thus being classified as Beginner and obtaining an overall score of 1.152. When compared to other companies in the same segment and size, 40.9% of the companies that have already responded to the Assessment were also classified at level 1. According to [30] "a company at this [beginner] level is involved in I4.0 through pilot initiatives in various departments and investments in a single area." Usually, they lack the resources to seek new directions outside their core competencies. Generally, these companies are not early adopters, mainly because of their fear of investing in the wrong technologies or adopting inadequate practices [15] When maturity models are applied to
SMEs, they often fall in the early levels, since maturity increases sharply with company size [30].

4.1 STRATEGY AND ORGANIZATION

I4.0 is more than just improving products or production processes using new technologies. In fact, it offers companies an opportunity to review and develop a new business model [33]. Regarding this dimension, the company studied was at level 0, the same level at which 70% of the companies in the same sector and segment are classified, as figure 5 shows. From the perspective of [30], the main barriers for companies to achieve higher levels in this dimension are related to the fact that I4.0 has little or zero impact on business strategy. Often, new cutting-edge technologies are not considered and implemented because the culture of the organization is not flexible enough [34]. Decision-making in these organizations is often based only on the manager's "gut feeling/experience" rather than on data and/or external information [15]. Thus, investments in I4.0 are scarce. SMEs need to redirect their business and development plans and include strategic goals and guidelines for a more coherent adoption of I4.0 technologies [33].

In this dimension, the company still does not have any indicator to measure the I4.0 implementation status. In fact, we can see that it is still necessary to define the overall business strategy, to better direct investments and projects.

4.2 SMART MANUFACTURING

Smart Manufacturing is the concept applied in productions where intercommunication between IT systems (MES, ERP, SCADA, ...) is possible. One of the main barriers to implementation is the high investment costs. Studies show that SMEs do not perform well when it comes to research and development. When compared to multinational corporations, SMEs lack IT integration, and, therefore, the software used for data analysis and processing is tailored to only keep records and solve routine problems [15].

The use of sensors on machines and systems at strategic data collection points is a prime feature of SM. The main goal is to enable a real-time capture of all essential data and process it quickly to assist in rapid decision making [30]. However, defining the best digital technology/tool or combination of tools for a given company varies on a case-by-case basis, as concrete objectives are necessary to support the implementation [35].
SM dimension, the company studied was classified at level 1, the same level as 13.4% of companies in the same segment and sector.

Currently, the company studied collects all production data manually, and later enters it into the ERP system. This system is well structured, but still needs to be integrated with shop floor data through the implementation of MES. This allows for a better perception of the manufacturing performance and definition of priority critical points. According to the authors of the model, the main challenges to evolving in the SM dimension are related to the lack of infrastructure, equipment not connected to IT systems, lack of data collection from machines and processes, and limited capacity for equipment infrastructure upgrades [30].

4.3 SMART OPERATIONS

Integration is the key to I4.0, in other words, the full integration of components and systems within the organization is an essential component for I4.0 development and can be considered the basis for horizontal and vertical value chain integration [36]. The central idea behind the integrated horizontal value chain is the interconnection of all internal and external value chain partners, from supplier to customer. Vertical integration, on the other hand, seeks the total alignment of departments within the same organization, that is, from product development, through the entire value chain, to product shipment. This connection is paramount to ensuring higher productivity, high quality, and flexibility [30]. Strong and transparent value chains are the future, so companies will have to adapt to the new environments and collaborate towards the same goal [14]. The company studied reached level 1, a figure reached by only 2.7% of the companies in the same sector and segment.

It is noticeable that the company is still characterized by a vision of local optimum x global optimum, that is, there is no sharing of information/data among the departments, and decision making is not aimed at prioritizing the company's results. SMEs generally have a smaller number of products to manage, and their collaboration network is not that strong, so, they do not have that many vendors/suppliers and there is a strong dependence on them [15].

With the integration of the manufacturing systems, a greater potential for information sharing among the areas is expected. When assessing the horizontal integration of the chain, there is no sharing of data online. Customers send a monthly overview of the demand, but the company cannot have an overview of the chain and
inventories. Regarding the technical assistance area, there is a proprietary system, but not an integration with the company's ERP, and the data do not connect. Looking at the other side of the chain, suppliers have a 120-day macro view of the company's demand but cannot track sales and inventories online.

[30] point out the following main obstacles to developing in this dimension: little or no system-integrated, in-company information sharing, and lack of initial strategies toward system-integrated information sharing with external partners.

4.4 SMART PRODUCTS

It is necessary to obtain the most comprehensive and accurate information about customers, which, with smart products, allows the company to be connected to the product itself while the customer already has it, so the company can be fed through data collection and information in real time [14]. Smart products are related to the development of products designed to favor new, data-driven services [37]. Thus, new products can be uniquely identifiable, so they can interact and record the characteristics of their environment through sensors and offer various additional functionalities in [15]. Within the concept of I4.0, a self-guided part/component tells a machine in the production process which step of the work needs to be done. To reach this level of interconnectivity, the product needs to have information about itself and about the work plan. This type of information can be collected through product features and memory [30].

In this dimension, the company studied was classified at level 2, where only 5.3% of the companies in its group (same size and segment) are. Based on an assessment with the company's team, it makes sense that this dimension presents better results than the others, because, as the company produces consumer goods, the end consumers expect and demand that the product has connectivity with other equipment in their home or commercial environment. As obstacles to improvement in this dimension, the authors of the model, [30], comment on the lack of analysis or use of data to optimize the product development process, that is, a feedback of market and aftermarket data to serve as input to new developments.

4.5 DATA-DRIVEN SERVICES

It is the evolution of companies from just selling a product, to also providing personalized services or solutions to their customers. For [30] the data-driven services dimension focuses on enhancing customer benefit. Within the concept of the fourth
industrial revolution, companies can digitalize their business models to transform them into new businesses with higher added value.

As for this dimension, the company studied reached level 0, which, when compared to its operating area, shows that 92.6% of the companies are at this level.

The company studied does not yet have skills in the DDS dimension, therefore, it should identify what its advantages could be and how it could leverage the potential of its product and the data collected to promote data-driven services to its customers. This would require a better integration with the customers, to understand what their priorities and needs are, and thus be able to offer them personalized services.

As the main barrier to this dimension, we can highlight companies' focus on traditional products, data-driven services are not offered, or there is no integration with customers [15]

4.6 EMPLOYEES

Employees are the key to ensuring that companies achieve their digital transformation. They are the most affected by the I4.0 scenario changes, thus requiring them to learn new skills and competencies [37]. This makes it an increasingly critical scenario for companies, since they need to prepare and ensure that their employees are qualified for the new environment, which requires adequate training and continuing education. Employees of SMEs are more likely to not participate in training, workshops, and mentoring, thus, there is a lack of participation and training of SMEs' workers in new approaches. Therefore, these workers are not able to keep up with current cutting-edge research institutes [15].

Unlike most SMEs, for the EM dimension, the company studied presented the best classification, reaching level 3, and the same level was reached by 11.2% of the companies in its group.

Aiming to prepare for the new work environment, the company has been investing in training and qualification within the I4.0 concepts, but it is noticeable that this action is still very much concentrated in the manufacturing area and should be extended to the other departments of the company, since this is also a prerequisite to start the vertical integration of the company. The barrier to evolution in this dimension can be identified as "skill sets not yet adequate in some key areas" [15].
4.7 ROADMAP TO 4.0

To increase competitiveness in the market, companies are strategically planning to move towards digital transformation, since the benefits offered create a cascading effect that everyone wants to achieve. However, this path is not easy and requires a long-term commitment to ensure that this transition is successful [38]. [39] state that there are very few roadmaps detailing the implementation of I4.0 concepts for SMEs, which can complement the fact that these companies cannot afford to lose money, so all decisions related to I4.0 must be very well calculated and aligned with the company's strategy. The literature shows that the main research studies that propose a roadmap for I4.0 implementation do not distinguish between large companies and SMEs, and still consider a large structure and multinationals' experience for this practice, but it is known that SMEs have a reduced structure, and their investments are more restricted when compared to large organizations [39].

In this context, as no ideal roadmap was identified to propose to the company studied, we used [39] as a guideline, where the authors proposed a more focused and practical roadmap to be implemented by SMEs. We did not follow every step of the model but used it as a guideline for this first roadmap of the company studied.

Before starting the design of the roadmap, we defined that it would be necessary to think about the I4.0 strategy for the company. Thus, the multidisciplinary team, the same team that answered the questionnaire, answered the following questions:

- What is the work's horizon?
- Considering the current level 1 in relation to I4.0, where do we want to get to?
- What are the main benefits we want from I4.0?
- How is I4.0 aligned with the company's strategic objectives?

As a result of the questions, we adopted the following I4.0 strategy for the company: Reach I4.0 maturity level 2 in the Strategy and Organization, SM and SO dimensions within 3 years. For the DDS dimension, the company is working on its strategic plan, so it will be prioritized in a second maturity assessment. The SP dimension has already been classified at level 2, so the decision was to keep working on the current products and propose improvements in a new assessment. For the EM dimension, even though it is already at level 3, the roadmap was defined as a priority, because it is necessary to expand the concept to the other departments in the company, and, because it is a very recent topic, it is necessary to constantly learn about it. The expected gains are...
as follows: increased manufacturing efficiency, reduced quality problems, and more reliable industrial data.

The roadmap proposed for the company studied based on the discussion with the multidisciplinary group is detailed in figure 2.

5 PRACTICAL AND MANAGERIAL IMPLICATIONS

There is a research gap regarding the appropriate maturity models to apply in SMEs. Therefore, this study has researched and presented the main maturity models available and that can be applied for SMEs to measure their maturity level in I4.0.

As practical contributions, it is noticeable that, before the maturity assessment, the company did not have a clear vision of its opportunities and where it should focus its resources. After the maturity assessment and visualization of the main gaps, the expectations for the next 3 years were aligned according to the organization's strategic plan, and we developed a customized and feasible roadmap to be implemented and thus the company reaps the benefits of I4.0. Besides the impacts for the company studied, this study can also contribute as a theoretical basis for the application of maturity and roadmap models for SMEs. Furthermore, in an indirect and more macro way, the results and deliverables of this research can serve as a foundation for future actions of entities and business groups in favor of the advances of I4.0 in the country.
6 CONCLUSION

Since 2011, when the Fourth Industrial Revolution started, SMEs have been facing great challenges due to emerging technologies and applications for the industrial sector [40]. We can say that the value creation that I4.0 has provided for manufacturing industries was unimaginable a few years ago [38]. Benefits of I4.0 include increased productivity, reduced product development and delivery time, improved quality, increased efficiency, and increased process visualization and control [41].

Due to financial, technological, and people challenges, the literature has been showing that SMEs need to be considered separately from large enterprises when making comparisons and implementation strategies for I4.0, as they lack resources and cannot develop at the same speed as large corporations [42]. Different studies present different models to assess the readiness/maturity of companies, but there is still no widespread and customized model for SMEs; thus, we selected one of the most popular models indicated in the literature to perform the evaluation of the company studied. The model we chose was the IMPULS model, which is already widespread and has been applied in different companies and segments. After applying the questionnaire, answered by a multidisciplinary team from the company, the conclusion was that the company is at maturity level 1 in I4.0, therefore, it is considered a beginner. Thus, focusing on the next 3 years of work, the company has designed a roadmap focusing on the 3 main dimensions with gaps in the assessment. This assessment was fundamental for the company to understand its current situation, and thus officially prioritize I4.0 within its strategy, which, until then, was being treated on demand by the manufacturing team. As it is a medium-sized company, the maturity assessment was essential to direct future work, since the company's investments are restricted and need to be well mapped out to ensure a good operating result. For the future, the company plans to reassess its maturity level every 3 years and update its I4.0 roadmap.
REFERENCES


[36] Ingaldi, M.; Ulewicz, R. Problems with the Implementation of Industry 4.0 in Enterprises from the SME Sector. Sustainability 2019, 12, 217


