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DIGITAL MATURITY: AN OVERVIEW APPLIED TO THE MANUFACTURING INDUSTRY IN THE REGION OF TÂMEGA E SOUSA, PORTUGAL

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Abstract. Digitalization is undoubtedly a major challenge for companies in the coming years. Applying a Design Science methodology this paper aims to describe the process for the development of a solution for obtaining an overview of the Digital Maturity in the manufacturing industry of the region of Tâmega e Sousa (an industrial region located in the north of Portugal). The evaluation process consisted of a sample of 53 companies that allowed to get a first picture of the region. Summing up, it is possible to say that a digital strategy is in the companies' plans with a focus on processes digitalization. In general, an overall digital strategy for the companies is in line with the marketing and human resources, in a middle position, with a few companies taking the lead, the majority following, and some others still now awakening to this reality.

Keywords: SME's Digital Transformation, SME's Digital Maturity, manufacturing, Tâmega e Sousa.

JEL Classification: M10, M15, O32, O33.

Introduction

Concepts such as Industry 4.0 (I4.0), digital transformation (DT), digital business models, artificial intelligence, smart factories, and many others related to these are used frequently in the business and academic world. This can be assessed through several recent research works on those issues, such as Manufacturing Industry (Ghosh et al., 2021; Singh et al., 2021; Gökalp & Martinez, 2021; Danuso et al., 2021); Industry (focus on Human Resources): (Konopik et al., 2022; Hallin et al., 2022; Ostmeier & Strobel, 2022); SME: (Yang et al., 2021; Matarazzo et al., 2021; Troise et al., 2022; Stich et al., 2020; Zapata et al., 2020); Transportation: (Tijan et al., 2021; Büyüközkan et al., 2021; Llopis-Albert et al., 2021); Education: (Pham et al., 2021; Iivari et al., 2020); Tourism: (Marx et al., 2021; Hadjielias et al., 2021).

Indeed, the issues of digitalization are inescapable. Furjan et al. (2020) present digital transformation as an inevitable path to survive in today's marketplace. The authors use expressions such as "Digital or Death" or "Digital Darwinism" to highlight the relevance of this issue.

The work presented here is one of the first results of a project that intends to perform an X-ray of the digital maturity (DM) level in the Tâmega e Sousa region, located in Northern Portugal. This paper presents the model and the tool used for this radiography. One of the goals is at first, based on the state of art, to identify the key elements to measure DM (Research Question – RQ1). The second goal aims to define the analysis process to measure DM on manufacturing firms, in the region of Tâmega e Sousa (RQ2). The third and final goal aims to get some results, based on a pilot questionnaire about the DM level of firms in this region (RQ3).

Thus, for an adequate analysis of the work carried out, 4 main sections were defined for this article: after the introduction, a brief literature review on the issues related to DM and I4.0 is presented, followed by the description of the methodology adopted, and a brief description of the region under analysis. Finally, the results achieved during the pilot phase will be presented.

1. Theoretical framework

According to Grebe et al. (2018) organizations that include digitization in their processes have advantages such

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as fast market entry, cost efficiency, increased product quality, and better customer satisfaction results. The authors also argue that companies with higher levels of digitization perform better.

Bearing in mind the role that digitalization and DT are currently assuming in several issues or daily life, and in particular in companies, this section aims to identify the critical factors that SMEs must consider towards a DT and I4.0 adoption.

Regarding the objectives of DT, there are several approaches, according to different authors, such as:

- Improve customer experience and engagement; Increase efficiency; Increase innovation; Improve decision-making processes; Transform processes and/or business models (Kane et al., 2015).
- Ensure digital readiness; Digitally improve products; Embrace product innovation; Develop new business models; Improve digital channels; Increase customer satisfaction and dialogue (Osmundsen et al., 2018).
- Flexibility, cost reduction, improved productivity, improved quality and reduced delivery time (Moeuf et al., 2018).
- Businesses redesign by introducing digital technologies, achieving benefits such as productivity improvements, cost reduction, and innovation (Ulas, 2019).
- Application of information systems aimed at improving business processes to increase efficiency, reduce costs and optimize business processes; Increase operational efficiency and market orientation; Create value; Promote interaction between organizations and consumers; Enable better understanding of requirements and facilitate customized new product offerings tailored to specific customer needs (Matarazzo et al., 2021).
- Reduce costs through automation; Increase revenues through enhanced customer experience (Verhoef et al., 2021).

Considering the elements presented, one can argue that DT aims to contribute to business excellence. It is also clear that excellence depends on several aspects (internal and external). So, in this new era, data and information in real-time for decision making are something that DT can promote.

The question that can arise by now is related to the readiness levels or to the extent that companies have already incorporated digital processes in their business models. In other words, how mature companies are in what regards DT or digital processes?

According to Eremina et al. (2019), DM describes the company's willingness and ability to change and apply innovative technologies, to remain competitive in the market. But, while maturity models[1] are focused on business processes, several authors present DM related to DT of an organization and that, obviously, also includes business processes (Chanias & Hess, 2016; Fletcher & Griffiths, 2020; Kane et al., 2016).

Following up on the definitions found during the research conducted, DT is defined as the implementation of innovative digital technologies to promote business improvements in an organization (Brown & Brown, 2019). These improvements must also occur at the level of organizational culture, as DT concerns both people and technology (Kane et al., 2016). DM, even though related to Information Technology concepts, should be analyzed from a broader perspective. It should reflect a management interpretation, describing what an organization has already achieved in terms of DT efforts, including product, service, and process changes (Chanias & Hess, 2016). DM can be presented as a holistic concept reflecting both technological and management perspectives, aiming at the success of companies through process optimization (Lahrmann et al., 2011; Teichert, 2019). According to Colli et al. (2019), a DM model describes what has already been achieved in terms of undertaking transformation efforts and how an organization systematically prepares to adapt to an increasingly digital environment to remain competitive.

Summing up, it is possible to argue that all these concepts (Maturity, Maturity Models, DT, I4.0) are aligned to promote business success (organizational excellence).

Even with a clear relationship between the digital and the business perspectives, DT and the increase of the levels of digital maturity in companies, the adoption and use of new technologies hardly are easily and quickly implemented (Fletcher & Griffiths, 2020). According to these authors, it is clear that organizations must improve their DM, that less digitally mature organizations are more fragile, and finally, that organizations with higher levels of DM are generally more flexible. The same authors concluded that digitally mature organizations recognize that external change is an ever-present aspect of business and have become capable to respond quickly and strategically. However, according to Zapata et al. (2020), several companies feel that they do not have the elements to define the current state of their transformation process. So, DM models as well as the elements included in these models are important elements to support those companies in the DT process. At the organizational level, the identification of the relevant elements to measure DM presents itself as a crucial goal for the companies' DT.

To identify the critical factors of DM, an overview of models allowed to identify three categories: 1) Digital Maturity Models; 2) Maturity Models for I4.0; and, 3) other relevant elements not associated with a specific model.

Several authors identified models, dimensions and items, as important elements to measure DM. Some of the examples identified are presented in Table 1:

From Table 1 it is possible to conclude that there are already several attempts to measure maturity in terms of DT and its positioning in the I4.0 trajectory. It is also

[1] Concept that that arises from quality management and first appeared in the 1930s. Since then, several maturity models have been presented. In general, these models aim to identify the level in which an organization is in terms of different maturity stages (Colli et al., 2019).

possible to see that there are different approaches, some science-based and others from a consulting perspective. Most of them are presented as a self-assessment model.

Table 1. Models, dimension and items

Model	Dimensions/ Items	Reference
The Digital Maturity Model 4.0	Dimensions: 4 Items: 7	(VanBoskirk & Gill, 2016)
Digital Maturity Model	Dimensions: 5 Items: 28	(Delloite, 2018)
Maturity Model of Digital Transformation (Education Organizations)	Dimensions: 6 Items: 27	(Ifenthaler & Egloffstein, 2020)
The Connected Enterprise Maturity Model	Dimensions: 2 Items: NA	(Rockwell Automation, 2014)
IMPULS Industry 4.0 Readiness Modelo adotado pelo IAPMEI (em Portugal)	Dimensions: 6 Items: 18	(Impuls, IW Consult, & FIR, 2015)
Industry 4.0 Self-Assessment	Dimensions: 10 Items: NA	(PWC, 2018)
Acatech – Industrie 4.0 Maturity Index	Dimensions: 5 Items: 20	(Schuh et al., 2018)
Maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises	Dimensions: 9 Items: 62	(Schumacher et al., 2016)
Smartness Assessment Framework for Smart Factories	Dimensions: 4 Items: 46	(Lee et al., 2017)
Industry 4.0-MM	Dimensions: 5 Items: 11	(Gökalp et al., 2017)
Adoption Maturity Model (for manufacturing companies)	Dimensions: 4 Items: NA	(Scremin et al., 2018)
DigiCoM – to assess digital employees competencies in industrial enterprises	Dimensions: 4 Items: 49	(Steinlechner et al., 2021)
Digital Maturity (not a model)	NA	(Brown & Brown, 2019)
Factors enabling Digital Maturity (not a model)	NA	(Salviotti et al., 2019)
How to Measure Digitalization (not a model)	NA	(Thordsen et al., 2020)
Requirements for Smart Manufacturing (not a model)	NA	(Mittal et al., 2018)
Pillars of Digital Transformation (not a model)	NA	(Kó et al., 2019)

The main dimensions present in different maturity models and also pointed out in the literature as key elements to consider are:

- Technology – Current existing level and adoption needs;
- Organizational culture – In particular the vision, customer orientation and openness to DT;
- Operations / Logistics – What processes are currently being executed, how they are executed and how they can be optimized (process);
- Organization – Can be related to organization strategy, culture or employee competencies - different models present different approaches;
- Strategy – This dimension is global, it is related to organizational culture, leadership, business model, among others. The organization should adopt a strategy that promotes DT;
- Employees – Skills and openness to embrace change;
- Products – The type of products offered, the level of customization, customer intervention in product development;
- Leadership – The example, commitment and support of employees in the DT;
- Customers – The type of relationship, communication and interaction;
- Business Model – Organization, regarding the internal and external strategy of the company, to support the DT;
- Marketing – In particular concerning the Customer dimension;
- Production and Processes – Related to the Operations dimension;
- Governance – Related to the employees' dimension.

Even after the identification of the most relevant elements, the factors to be included in a maturity model must take into consideration the specific environment and characteristics where the model will be implemented. To define the dimensions of a DM model Thordsen et al. (2020) suggests a conceptual research method using, for example, interviews. This approach will lead to a more effective model for measuring maturity levels and will help in defining the next steps. In other words, the definition of a maturity model should first consider the factors that are generally accepted as valid (according to the literature review), and then be validated on a case-by-case basis before application.

Gökalp and Martinez (2021) argue that the models (to be built) should consider expanding the analysis to focus not only on operational excellence but also on expanding the product and service portfolio by creating smart products. Second, the dimensions included in the model design should include all stakeholders who will have some kind of impact on the business transformation. Finally, these authors also argue that it is fundamental to the usability of the models that they must be accompanied by tools that identify improvement proposals that help in the selection of the best options for each case. All these elements are relevant to the solution proposal intended for the Tâmega e Sousa region.

Even though the need for strategies to support the adoption of digital technologies is recognized, there are some constraints mainly for SMEs, such as:

- Financial limitation, limited knowledge and awareness of the technology (Masood & Sonntag, 2020);
- Change Cost-benefit (Erol et al., 2016; Zapata et al., 2020);
- Lack of expert support for adopting new technologies (Erol et al., 2016; Ingaldi & Ulewicz, 2020; Zapata et al., 2020);
- Budget shortcomings, high operational costs, inability to understand technologies, insufficient information on digital standards (Ulas, 2019);
- Data security, privacy issues, difficulty in terms of technological developments, unawareness of the benefits of digitalization or lack of qualified resources (Ulas, 2019);
- Lack of digital knowledge (internal level) and digital presence (external level) (Hallin et al., 2022; Konopik et al., 2022; Ostmeier & Strobel, 2022; Ulas, 2019).

DT goes beyond the improvement of products and processes, to affect business models and management aspects of all processes in the value chain, creating new challenges for companies (Bleicher & Stanley, 2016). These new challenges are not exclusive to larger companies. As argued by Toanca (2016) this path should be taken by both large organizations and SMEs.

Given the challenges of digitalization and the objectives of this research work, we then set out to analyze the main dimensions of DM. Table 2 presents the dimensions considered as the most relevant for this research.

Table 2. Digital maturity dimensions

Dimension	Brief Description
Strategy	Overall approach
Business Model	How the organization is aligned with digital transformation
Technology	Current level and identification of needs
Organizational Culture	Vision, customer orientation, and openness to embrace digital transformation
Employees	Skills; openness to change
Leadership	Example, commitment and support for employees in digital transformation
Governance	Related to the employee's perspective
Operations/ Logistics	Identification of what processes are being run, how they are being run, how they can be optimized
Production & Processes	Related with operations
Products	Type of products offered; level of customization
Customers	Type of relationship, communication and interaction
Marketing	Related with Customers

Based on the literature review, the main dimensions defined for the analysis tool to be applied in the manufacturing industry of the Tâmega e Sousa region were: **Strategy** (strategy and business model), **Technology, HR Processes** (organizational culture, employees, leadership, governance), **Production Processes** (operations/ logistics; production & processes), **Marketing Processes** (customers, marketing), and **Products**.

In conclusion, after the analysis of the state of the art, six dimensions were identified as the most relevant to analyze the DM in the manufacturing companies of the Tâmega and Sousa region.

Considering that from the analyzed models, several present a consulting basis, which is understood by its proximity to the business fabric, for the development of this tool, it was used a mixed approach joining academic knowledge to business knowledge by creating a project team that relies on the collaboration with a company linked to the innovation consulting area. The following section presents in some detail the approach used in the execution of this project.

2. Methodology

To address the objective for this research it was first performed a literature review in order to identify the most relevant elements to measure DM. This research was developed in the previous section. Aiming RQ2 – Definition of a process to measure digital maturity was applied the Design Science methodology (Eekels & Roozenburg, 1991; Hevner et al., 2004; March & Smith, 1995). This methodology is globally accepted in several sciences and is very frequent in the development of artefacts in information systems. Design science methodology creates and evaluates IT artefacts intended to solve identified organizational problems. In this particular case, the problem is related to the difficulty in measuring the DM level, leading to another problem which is the level of the digital readiness of firms. After a literature review, it is possible to conclude that the most frequent way to measure DM is through web platforms. Most of these platforms are generalist, and that is the justification to develop an alternative platform aiming at the measurement of a specific sector (manufacturing) in a specific region (Tâmega e Sousa, Portugal).

Thus, and taking into consideration the basic assumptions of this methodology (construction and evaluation) it was adopted a step-by-step model. The steps are presented below, and the final result is in Appendix 1.

Along with the Design Science methodology, it was also followed the principles of the action-research methodology, using its iterative process in the improvement of the analysis questionnaire.

The steps of this methodology are briefly presented below:

- Step 1: Identification and validation of the problem followed by literature review – Given the nature of this project, the research focused both on models

found in the state of the art, and on consultants' models, which are the most recognized in the business world.
- Step 2: Identification of the most relevant dimensions, sub-dimensions and analysis items – The dimensions and sub-dimensions identified through the literature review were organized and grouped through conceptual mapping. Through an iterative approach, the dimensions and sub-dimensions were organized seeking to answer the following question: Which dimensions allow an analysis of the DM of manufacturing companies, generally small/medium-sized, in the specific universe of the Tâmega e Sousa region?
- Step 3: Questionnaire development (joint work between the research group and the consulting firm) – In this step, the 6 dimensions identified in Table 4 were divided into sub-dimensions and items for a detailed analysis of the companies' maturity level. According to the state of the art, these dimensions are framed in 3 axes of analysis: Product, Processes and Strategy. The development of this questionnaire also considers the indicators for monitoring DM.
- Step 4: Development of the platform to support the collection and analysis of the questionnaires and automatic generation of the self-diagnostic report – Initially, and because of the pilot testing phase, the platform had two essential functions: (1) collection of questionnaire data, the first questionnaires being conducted in a semi-structured interview format, and (2) automatic and immediate processing of the data for sending a self-assessment report. Although these are the functionalities foreseen for phase 0 of the platform, other more complex analysis functionalities have already been defined for the next sprints, and are currently under development.
- Step 5: Validation through practical application (pilot tests) – Finally, the tool was tested in real industrial environments for data collection. The feedback obtained was aimed at improving and clarifying the concepts addressed in the questionnaire.

Since the analysis tool developed has as the main objective the study of the DM in the region of Tâmega e Sousa, the next section presents a brief description of the region giving special attention to issues associated with digitalization.

3. The region

Tâmega e Sousa is a NUTS III sub-region, located in Northern Portugal, as shown in Figure 1.

This region is located in a transitional region between the Metropolitan Area of Porto and Trás-os-Montes. This means that Tâmega e Sousa consists of urban, rural and industrial areas that blend together, giving it a rich and heterogeneous territorial pattern, characterized by distinct landscapes (Pereira, 2020a). Its economy stands out for a marked industrial aspect, characterized by decades

Figure 1. The region of Tâmega e Sousa

of tradition and knowledge that contribute to the primacy demonstrated in several of its industrial sectors: Footwear, Furniture, Metalworking, Textile and Clothing, and Agri-food (which includes wine and viticulture). Each sector presents distinct development stages and multiple needs, which must be analyzed in light of the capabilities, priorities, and objectives of each company. Bearing in mind the regional diversity, in terms of development among companies and sectors, was developed a solution to analyze companies' DM. The results will contribute to the definition of innovation, research and technological development projects to meet the specific needs of each company.

Pereira (2020b), in a study about the competitiveness of this region, presented some conclusions related to the digital picture in the region that are interesting to highlight here:
- If the region does not know how to follow the trends of I4.0, it will tend to lose its competitive advantages to other players, national and international, and become a "prisoner" of its own specialization.
- Productivity differs not only across sectors but also across companies of different sizes: large companies are generally more productive and competitive than SMEs. This point should be taken with particular attention since the latter constitute almost 100% of the business network of the region.
- The issue of human resources (HR) acquires a key role until 2030, considering the expected impact of digitalization and automation of the economy (I4.0). In addition to the workforce requalification, companies should invest in a design thinking strategy, anticipating the future framework and new trends in the labour market.
- There is an insufficient articulation between academia and business, which reduces the effectiveness of the innovation system. It is advisable to develop projects of regional scope, with a specific focus on strategic sectors and the involvement and commitment of all actors: companies, local government, higher education, industry associations and technology centres.
- There is a social overvaluation of what innovation is, leading companies to invest in innovation for the least appropriate reasons, presenting a greater strategic fragility. A large percentage of projects end up "dying" prematurely (when investment projects and incentives end, for example).

Aware of this reality, and assuming the lack of knowledge about the DM of Tâmega e Sousa's industry, the Digital Industry Survey[2] (DIS) project was implemented.

4. Results

After the development of the tool to collect the data about DM in the region of Tâmega e Sousa, the research proceeded with the validation through practical application (pilot tests) – step 5 of the design science methodology.

A total of 53 answers were received. Three of these answers are not from a municipality of this region, but from a neighbour municipality that shares very similar characteristics. For that reason, and since these are not the final results, these 3 answers were also considered for the analysis.

The first results allowed to conclude that most of the answers were obtained from one municipality (Felgueiras – 42%). From the 11 municipalities that compose this region no answers were obtained from three: Baião, Cinfães and Resende. Considering the activity sectors, 26% of companies are shoemakers, 15% produce furniture, 17% are from the textile industry, 13% are on metalworking, and the same percentage of companies operate in the food industry. The remaining operate in other manufacturing sectors. In regards to the number of workers, 43% of the respondent companies are classified as medium firms, 32% as small, 15% as micro, and 9% as large companies.

The next results to be presented are related to the knowledge of I4.0 concepts and the planning of digital activities. Surprisingly (or maybe not) 38% of the respondents declare they completely ignore the concepts of I4.0, while 41% are familiar with the concept and technologies and are already implementing some of them in the company. The results about the activities planned or implemented are presented in Table 3.

Table 3. Digital activities planned or implemented

	Processes Digitalization	Smart Products	Systems and equipment integration	Full Digital Marketing Strategy	HR Training for Digitalization
Not applicable	6%	25%	13%	8%	6%
Not in the company plans	2%	17%	11%	15%	15%
In the company plans	36%	32%	40%	36%	38%
Under implementation	32%	8%	17%	26%	28%
Implemented	25%	19%	19%	15%	13%

[2] https://digitalindustrysurvey.estg.ipp.pt/

From a first analysis of the digital activities planned or implemented it stands out that, for all the activities, the most frequent answer was "in the company plans". Further and detailed analysis is required, but it is clear that some companies and their management are already working on digitalization, while others are aware of this reality.

When respondents were asked about the relative importance attributed to smart products, smart processes and smart strategy, processes took the first position with an average figure of 43%, then smart strategy with 38%, and smart products with 19%. The focus is on the transformation processes, not so much on the products. Regarding the weight of smart products in total turnover, 28% do not have smart products, and 34% of companies indicate smart products turnover under 10%. Only 13% of respondents argue that smart products represent half or more of their turnover. 25% of companies indicate that smart products turnover is somewhere between 10 and 50%. These figures may justify the low importance attributed to smart products.

Getting back to the analysis of relative importance, among the different processes, the results show that production and logistics processes take the leadership with 33%, followed by sales processes with 27%. If the first makes sense when compared with the relative importance attributed to the processes dimension, the latter creates some noise, since smart products are not the companies' priority. Are firms following a strategy of selling the same products, but trying to produce them more efficiently? This is a hypothesis that may be possible, considering the type of products offered in this region, but needs some more research. To close the relative importance of processes dimensions marketing takes the 3rd position with 18%, then IT with 13% and the last one HR and finance with 9%.

Still considering the "products" theme and combining it with the marketing process, it was also asked about the level of digital marketing strategies. 22% of companies declare that marketing strategy is mostly digital, while 15% still do not use any digital type of marketing. 23% declare to have a low level of digital marketing – most of the actions follow the traditional (non-digital) strategies. The majority of companies (40%) declared to be at a medium level by using some digital marketing tools.

Talking about companies' digitalization, it is important to know how prepared the company is in terms of IT support. The higher the level of automation the more important is a quick answer in terms of IT experts in case of any occurrence. As a first recognition, it was asked how embedded are IT in the company daily life. Only 21% of the respondents have an IT department. 43% have an IT outsourcing agreement, and 36% just ask for an expert when necessary (sporadic contacts). However, it is interesting to notice that most companies do not have an in-house IT department, but 42% of companies have an in-house R&D department.

The low importance given to IT in company processes may be one justification for the levels of automation

in these companies (11% without automated processes. Most companies (40%) present a partially automated production line or some machines that replace HR (32%). Only 8% of the companies have the entire factory automated.

Implementation success is highly dependent on HR competencies. In Table 4 is it possible to find a summary of the competencies level at several digitalization requirements, identified by the respondents.

Table 4. Human Resources competencies level

	Non-existent	Existent, but under-developed	Existent and well developed
Technological Infrastructure	23%	55%	23%
Automation	32%	47%	21%
Data Analysis	23%	60%	17%
Data Security	19%	40%	42%
Support Systems	26%	51%	23%
Cooperative Software	30%	38%	32%
Non-Technical Competencies	23%	53%	25%

The results seem to be clear: Companies argue that in general HR hold the requirement to implement a digital strategy, but most of them are still at an underdeveloped level. The exception is the competencies in data security, probably due to the GDPR applied in Portugal since 2018.

After HR, management is another important player. On what regards the management perspective, the first results suggest a balanced strategy for digital strategy implementation, as can be observed in Figure 2.

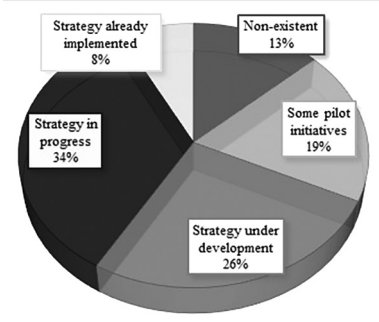

Figure 2. Digital strategy implementation in companies

From Figure 1, it is possible to say that 42% of companies are with digital strategy implementation in progress, or already implemented. At the same time, 45% of companies are already acting on what regards a digital strategy implementation. These figures are somehow aligned with the results obtained on the question about the commitment levels of the management team towards a digital strategy. On the one hand, 15% of companies acknowledge that the leadership team does not recognize the value of a digital strategy. On the other hand, 34% recognize wide support from the leadership team towards the implementation of a digital strategy. Once again, the majority (51%) are in an intermediary position: leadership recognizes that financial benefit can be obtained from digitalization, and are developing investment plans.

The results concerning data collection processes are also worth mentioning. The DT of companies depends on several factors, some of which are briefly discussed in this section. A relevant one is data collection and analysis efforts. If the company seeks to support decision-making on data, data must be collected. In general, companies in this region are already aware of this necessity since 74% of companies are doing data collection, but this means that there are still companies (26% in this sample) that are not doing it.

In general, one can say that the region has conditions to move to a general digital strategy, but there is still a long way to go.

Conclusions

From the literature review and the analysis performed under this research, as final remarks, it can be stated that some key dimensions must be taken into consideration to measure DM. Replying to RQ1: "What are the key elements to measure digital maturity?" Those dimensions were grouped into three categories: **Products**, **Processes**, and **Strategy**. The products dimension was analysed from the perspective of smart products. In the manufacturing industry of Tâmega e Sousa, this was considered as the less relevant dimension. Processes dimension, which includes **Technology, HR, Production** and **Marketing** processes, was considered the most important, in the sample of this research. This importance might be justified since the sector under analysis is the manufacturing sector, so the focus is mainly on production. The Strategic dimension, in terms of relevance, was considered the middle dimension.

In what regards RQ2 "how to define the analysis process to measure DM in manufacturing firms, in the region of Tâmega e Sousa?" it was developed a tool, supported by the flow chart presented in Appendix 1. This flow chart and the tool associated were developed in an academic – consultancy partnership, in order to reach the firms with effective communication.

RQ3 aimed to present some general results on the DM level in the studied region. The results were presented in the previous section, but the most relevant can be summed up as follows: (1) Some companies are leading the digital transformation of their companies, while others are aware of this reality. (2) In a region that depends mainly on its manufacturing sector, automation levels are very low, and even the importance given to IT is, in a way, worrying -only 21% of the respondents have an IT department. (3) In most cases, the average results for the

analysed strategies (marketing, HR, commitment to DT) point to a balanced situation, on what regards processes digitalization. There is a need to support companies in their DT process.

Disclosure statement

The Authors state that have not any competing financial, professional, or personal interests from other parties.

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APPENDIX 1. TOOL IMPLEMENTATION FLOW CHART