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CASE STUDY

Digital transformation in e-commerce logistics: a case study on the digital maturity of the last-mile area

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ABSTRACT

Highlights: This article addresses the diagnosis of digital maturity in e-commerce logistics, specifically the final delivery stage, known as the last-mile. The last-mile has greater digitization demand than traditional logistics due to the extreme speed of the virtual world during shopping, where customers transfer these same expectations to delivery services.

Goal: The main objective of this work is to evaluate the digital maturity of the last-mile area of operation of an e-commerce logistics company.

Methodology: This study evaluates the maturity model in a case study with the company E-commerceCo. Interviews were conducted with key employees for data gathering.

Results: The proposed method allows defining and analyzing the digital maturity of the last-mile area of the company in question, understanding strengths, such as a culture open to innovation and digitally mature, and weaknesses, such as technical limitations imposed by the main system used and lack of cybersecurity barriers.

Limitations of the investigation: Since it is a single case study, it does not allow a broad generalization to industries in other branches. Another limitation is that this study is focused on Brazilian logistics operations, which may differ from other countries.

Practical implications: This research is relevant to serve as a reference for other companies in the e-commerce logistics sector to assess their digital maturity from the proposed model and compare common challenges and opportunities. In addition, it will help the studied company to create a successful digital transformation strategy.

Originality / Value: We propose a new approach on how to evaluate the digital maturity of the last-mile area of operation of an e-commerce logistics company.

Keywords: Digital Transformation; Digital Maturity; E-commerce; Logistics; Last Mile.

INTRODUCTION

Digital transformation has been identified as one of the biggest changing trends in society and companies, both in the short and long term (Tihinen et al., 2016; Hossainet al., 2023). Additionally, it is one of the main challenges companies face today (Korchagina et al., 2020; Saarikko et al., 2020). According to Anderson & Lanzolla (2010), the remarkable progress of digital technologies and the increasing diffusion and reliability of high-speed Internet services have radically reshaped companies' business models and operations. According to Correani et al. (2020), many companies have adopted a digital transformation strategy to transform how they create appropriate value. The last-mile logistics in e-commerce were not left out.

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Digitization in the delivery of orders is one of the main movements in the sector, which seeks to bring convenience, flexibility, and low costs to customers (DHL Group, 2018).

According to Barrett et al. (2015), digitalization in the logistics and supply chain management sector is increasingly important for companies. Companies such as Amazon (Rodrigue, 2020), Tesla (Bruijl, 2017), and Loggi (Vincenzi et al., 2021) have part of their logistics operations as digital or supported by digital processes. Furthermore, this trend is not only perceived in leading companies in digitalization but in the entire market. According to o DHL Trend Radar (2020), big data analytics digital technology is increasingly part of the logistics industry's operating model and cloud-based computing, which has been growing because logistics companies understand its scalability, cost-effectiveness and reliability.

Within the context of logistics, there are several areas of activity. However, the sector studied here is e-commerce logistics, specifically the final delivery stage, known as the last-mile. E-commerce logistics has a different delivery profile than traditional logistics and a greater demand for digitization; as Melo & Fernando (2017) say, "With the virtual world being extremely fast and accessible during purchases, customers transfer these same expectations to the delivery services, which has become a major challenge for carriers". Thus, new technologies and applications are being used in last-mile delivery to make improvements, such as reducing costs and optimizing routes (Jucha, 2021). However, twenty percent of senior executives do not know where to start the digital transformation process in their companies (Caetano, 2021), and digital transformation can fail due to the disassociation between strategy formulation and implementation (Correani et al., 2020). Góes et al. (2019) and Zapata et al. (2020) state that digital transformation in companies and institutions must start with identifying digital maturity, not only to diagnose the current condition but also to understand the different levels of maturity between the areas of the company. It helps prioritize, approach, and create the digital transformation plan.

Considering the challenges and opportunities that involve digital transformation in companies and highlighting the e-commerce logistics sector and the last-mile stage as a great challenge, we pose the following research question: What is the last-mile digital maturity level in a Brazilian e-commerce company? Thus, this work aims to diagnose the degree of digital maturity of the company's last-mile and understand points of challenges and opportunities. It is based on a single case study with a medium-sized Brazilian e-commerce logistics company. With the findings of this study, the company may advance in its digital transformation process.

RESEARCH BACKGROUND

Last-mile delivery

The operation of e-commerce logistics (Figure 1) begins with storing products in the physical facilities of e-commerce. Upon receiving an order, the products are separated and collected by a specialized carrier, which takes them to a centralizing hub, where the volumes are concentrated and separated by destination. Subsequently, they are transferred to another unit of the carrier. This process is repeated until the products arrive at the local distribution centre, where a delivery person takes them to their destination (Bergmann et al., 2020; Dumanska et al., 2021; Monteiro et al., 2021). The intermediate step at the hub is known as cross-docking. It consists of the transshipment process, through receiving products at the facility, sorting, and redirection for dispatch without storage (Ladier & Alpan, 2016; Van Belle et al., 2012). In the cross-docking strategy, products are only on premises for a short period, usually less than twenty-four hours (Moghadam et al., 2014). Finally, the last-mile stage is the last stretch of the supply chain, going from the last distribution centre to the final destination (Lim, 2018; Gevaers, 2009). According to Boysen et al. (2021), standard last-mile delivery is based on human-driven delivery vehicles leaving a central warehouse, where couriers route through each delivery destination.

The last-mile is often characterized as one of the supply chain's most expensive, inefficient, and polluting steps (Gevaers et al., 2014; Maître et al., 2022). According to Melacini (2018), this step is one of the main challenges of e-commerce. In addition, the last-mile is important to the company since good performance in the last-mile stage is related to a better evaluation of the consumer's online experience and greater customer satisfaction (Vakulenko, 2019). Moreover, the last-mile stage is the point of contact where the order reaches the end consumer. So, it become the key to customer satisfaction (Ko et al., 2018). Another challenge of this area of logistics operation is that since the last-mile covers delivery to the final consumer's home, a recipient must be at home to receive the goods. It creates additional complexity in operation management (Melacini et al., 2018). In addition, the profile of e-commerce delivery is about a few volumes for each address, so that routing deliveries can become a highly difficult task (Melo & Fernando, 2017). Finally, forecasting is also a challenge in e-commerce logistics since it involves several variables, making it difficult to be precise (Novaes, 2007). Given all these challenges, e-commerce logistics has a high freight value per

unit. Since there is a loss of scale, the fixed freight cost, which used to be diluted by several units, is now concentrated in a few volumes (Melo & Fernando, 2017). Considering the entire e-commerce logistics chain, the last-mile represents about 50% of the total cost (Roumboutsos et al., 2014).

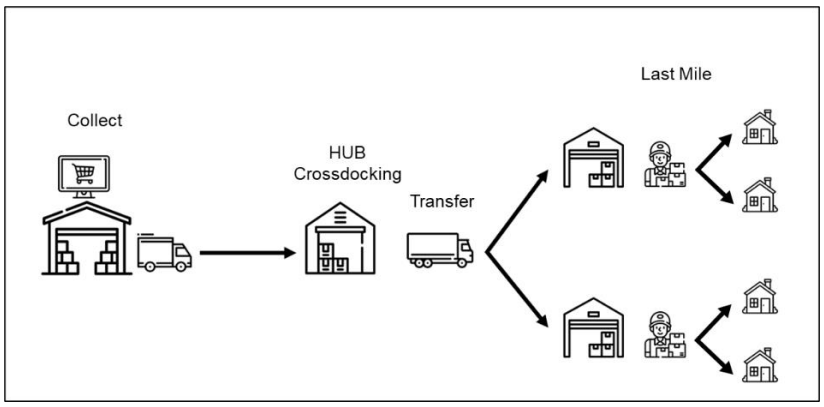

Figure 1 - Stages of the e-commerce Logistics Operations
Source: Created by the authors according to Ko et al. (2018) and Gevaers (2013).

Technology use may optimize logistics-related processes, and promoting the best purchase experience is important. Integrating communication between the last-mile logistics operations and the final consumer via technology can promote a paradigm change (Petrovic et al., 2013). Besides, information technology must reach a stage where the systems will integrate all those involved in the last-mile process from end to end. An example of this integration is the functionality developed by the American company UPS, in which recipients, through a digital system, can view alerts of their deliveries, receive information on the status of orders, insert instructions for delivery time windows and even authorize delivery to other people or change the receiving address (Petrovic et al., 2013). Thus, a digitization strategy increases customer engagement and satisfaction and reduces operating costs. Therefore, digitalization in companies can build a strategic advantage in the future, creating a difference in the competition (Alina, 2018).

Digital transformation in the last-mile delivery

According to the DHL Logistics Trend Radar (2020), technology disrupts logistics business. Around three thousand startups are developing new products, services, and business models involving logistics. The possibility to collect and analyze a vast amount of data and improve the visibility and connectivity of information combined with a network with multiple delivery options will have a relevant impact on logistics productivity (Herold et al., 2021).

During the COVID-19 pandemic, supply chains and logistic operations needed many changes to move essential items, even with the imposed health restrictions (Toy et al., 2020). This situation allowed the technology to prove its benefits to several companies, creating technological solutions to maintain operations (Toy et al., 2020). An example is the Brazilian company Diálogo Logística, which replaced the written signature that proved the receipt of orders with a voice signature model, avoiding contact between the receiver and delivery person.

According to Kaji et al. (2019), the five biggest challenges to carrying out digital transformation are the existing operational structure, the lack of prioritization, the updating of legacy systems or processes, the lack of talent with the necessary skills, and the company culture that is averse to change. However, according to the report DHL Logistics Trend Radar (2020), as soon as companies digitize their processes, they perceive an increase in transparency and flexibility gains, which generates more demand for digitization. A similar situation occurs with customers, who begin to see the benefits of digitization with better efficiency, service level, and communication. When looking to assess what a company has already achieved and how it is prepared for future changes in terms of digitalization, the definition of digital maturity emerges. (Teichert, 2019).

The term "maturity" means the state of being complete or ready, and it is the result of the development of a system (Lahrmann et al., 2011). Digital transformation and digital maturity are often seen as the same concept (von Leipzig et al., 2017), but digital maturity is a systematic way for the organization to perceive its transformation (Kane et al., 2017); therefore, "digital maturity" reflects the state of a company's digital transformation. (Chanias & Hess, 2016). Digital maturity

goes beyond a technical interpretation that reflects the technology sector's performance; it also encompasses a managerial vision when describing the company's achievements in digital transformation regarding changes in products, services, processes, skills, and culture (Chanias & Hess, 2016). Therefore, according to Teichert (2019), digital maturity is holistic, both technical and managerial, and is not static because the digital scenario is continuously evolving.

In order to assess an organization's level of digital maturity and guide it to increase its maturity, there are models that, based on established dimensions and criteria, analyze the company's situation and which are the main directions to increase its digital maturity (Becker et al., 2009; Berghaus & Back, 2016; Pöppelbuß & Röglinger, 2011). In the literature, several models for evaluating digital maturity with different approaches, such as the Maturity Model for the Delivery Process (Felch et al., 2018), emphasize logistics. The model proposed by Santiago da Costa et al. (2018) focused on small companies, the model presented by Westerman et al. (2012), which stands out for its internal and external view of the assessed company, amongst others that were analyzed by Góes et al. (2019).

The Acatech maturity model

In this study, the digital maturity assessment model of the German institution Acatech is applied (Schuh et al., 2020). It is motivated by several aspects. First, it is a model with wide application possibilities due to detailed application instructions. Second, the reputation of the creating institution, namely the German Academy of Science and Engineering, is high. Third, the model is methodologically rigorously created, timely/up-to-date, and tested in several types of industries and maturity levels.

In this study, other three other relevant models from the literature were analyzed before choosing the Acatech model: the Digital Readiness Assessment Maturity Model (DREAMY) (De Carolis et al. 2017), the IMPULS model of the German Engineering Federation (Lichtblau et al. 2017) and the Schumacher Model (Schumacher et al. 2019). The models mentioned above are described in Appendix B. When choosing a maturity model to assess a last-mile operation, it is important to consider its specific context, goals, and challenges. Each of these three maturity models has its strengths and limitations. The DREAMY Model is tailored to manufacturing and industrial companies. Its applicability could be limited if the last-mile operation is not primarily focused on manufacturing processes. The IMPULS model was applied in mechanical engineering industries, which might not capture the nuances of a last-mile operation. So, it might not cover all the relevant aspects of a last-mile operation, such as customer interactions, delivery optimization, and real-time tracking, which are crucial in last-mile logistics. Finally, the Schumacher Model is designed to assess Industry 4.0 readiness and maturity. If the last-mile operation is not heavily aligned with Industry 4.0 concepts and technologies, this model might not be directly applicable.

Therefore, the Acatech model was chosen since it contemplates a broader organizational vision of digital maturity and its worldwide recognition in Industry 4.0. It is essential to understand that applying the models will depend on what the organization thinks about digital transformation and, mainly, on its purposes and strategic objectives (Pacchini et al., 2019). In addition, the methodology of each model is unique, and its employability is useful for a company to start the transformation process.

The model developed by ACATECH (National Academy of Sciences and Engineering of Germany) was originally developed in 2017, called Industrie 4.0 Maturity Index: Managing the Digital Transformation of Companies. The model aims to make the company an agile and learning organization, capable of continuously adapting and making quick decisions in a disruptive environment (Schuh et al., 2020). Thus, it focuses on four key perspectives or structural areas of the organization, and each of these key perspectives encompasses two fundamental principles:

1. Resources: Resources represent machines, equipment, tools, materials, products, and human resources. Its principles are capability digital and structured communication.
2. Information Systems: Information systems (IS) are systems for generating and providing information and knowledge. Its principles are information processing and information systems integration.
3. Organizational Structure: The organizational structure (EO) describes the rules and structures necessary for the company's internal organization (structural and operational processes) and for the external organization (position within the value chain)—dynamic collaboration within the value network.
4. Organizational Culture: Finally, culture encompasses the value system within the company and is largely determined by the behavior of employees. Its principles are disposition to change and social collaboration.

Companies must use the ACATECH model as a basis for developing their own roadmap with

capabilities that are adapted to the company's current situations, and to its strategic objectives. Based on these capabilities, each structural area is then individually assessed through six maturity levels, as shown in Figure 2. These levels are: (1) Computerization; (2) Connectivity; (3) Visibility; (4) Transparency; (5) Predictive Capability; and (6) Adaptability (Schuh et al., 2020). Figure 2 details the model under discussion.

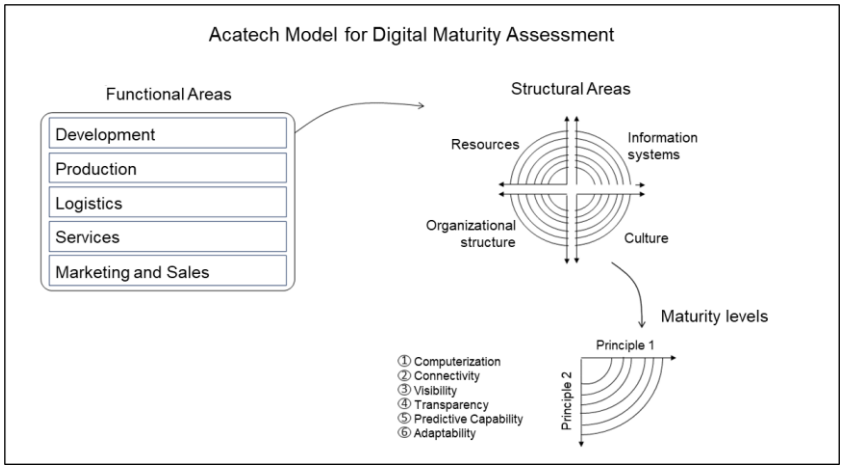

Figure 2 - Acatech Model of digital maturity assessment
Source: Created by the author according to (Schuh et al., 2020).

METHODOLOGY

To carry out our study, we opted for an exploratory case study approach, which appropriately addresses new research areas (Yin, 2018). In addition, as studies on digital transformation in last-mile logistics are still successful, using a case study helps to understand still unknown variables and misunderstood phenomena (Benbasat et al., 1987). Based on this, following the guidelines for carrying out case studies in the management of operations proposed by Voss et al. (2002), we sought to develop a research framework, special cases, and sampling, define research instruments and data collection procedures, carry out the field study, code and document the data and, finally, analyze the data.

Selection and sampling of cases

According to Meredith (1998), the single case study is the most applicable method for new exploratory investigations, as an extensive qualitative description and contextual and temporal analysis characterize it. Therefore, as we intend to study a new and unexplored field of research, the theme of digital transformation in last-mile logistics, carrying out a process of evaluating the digital maturity of a Brazilian e-commerce logistics company, the single case study is suitable for this purpose.

The unit of analysis of our study comprises a medium-sized Brazilian company in the e-commerce logistics sector with the fictitious name of "E-commerceCo". The company's main customers are retailers who sell through websites and outsource the product delivery operation. Currently, the company operates in several states of Brazil and is in the process of expansion.

E-commerceCo operates on a model with few assets; therefore, it does not have its own fleet, and local and independent partners carry out the operation. Thus, the studied company's biggest differentials are managing these partners and customer service. The company's assets are the hubs and some local distribution centers in certain strategic cities, habitual capitals with high demand. The areas that are directly involved with the logistics operations are divided into three: (i) Transport, responsible for collections and transfers between units; (ii) Hub, responsible for managing the company's hubs; e, (iii) Last-mile, responsible for the last stage of delivery.

This study focuses on the last-mile area. The last-mile area ensures fast and inexpensive delivery from the local distribution center to the destination of the goods, usually the recipient's home. The company practices two last-mile models. The first is where the company itself manages the distribution center. An in-house team manages and liaises directly with delivery partners. In the second, the distribution center belongs to a partner. Therefore, the team that manages and contacts the delivery person is outsourced, usually a local logistics company. In both cases, the

systems and technology used are those of the company studied.

In terms of technology, the company's last-mile under discussion uses three systems: (i) a third-party transportation management system, which allows for the most basic control of the operation and systematically tracks the order, from collection to final delivery; (ii) a proprietary application used by delivery partners, which performs the sequencing of deliveries, facilitates their management for the delivery person and provides real-time information about the order; and (iii) a proprietary management system focused on managing couriers based on application data. The three systems are related and play complementary roles. Regarding the separation of the route of each delivery person, the company studied performs the fixed routing. Each distribution center systematically divides its region into several delivery sectors. When an order from a customer enters the system, the transportation management system already characterizes that order as being from a certain sector, regardless of how many other orders are in the same sector or in the same center.

Research instruments and data collection procedures

Among the main qualitative research instruments are structured interviews and participant observations (Voss et al., 2002). We performed the analysis in our study based on these two sources to improve its validity and reliability (Patton, 2002). The interviews are semi-structured and carried out by the author, in person and remotely, with employees of the studied company who are involved with the last-mile area; the employees interviewed are the founder and CEO, the general manager of operations, the last-mile manager, the owner last-mile coordinator, the control tower supervisor, and the digital products area supervisor.

In addition to defining the research instruments, there must be a research protocol that details the data collection procedures for methodological rigor (Yin, 1994). In this case, the interviews were used for the rounds during the script's construction, and a structured guide with open questions was used (Appendix A).

Field study, coding, and documentation of data

According to Voss et al. (2002), to carry out a case study in the area, we must seek contact and observe the individuals/processes that have the best information about the data of interest, using the research protocols developed for this. Thus, the author closely followed the last-mile logistical processes concerning participant observation. According to Yin (1994), qualitative data should be transcribed for better coding and documentation so that notes, recordings, and photos are taken during observation and meetings of the participants. In addition, all interviews conducted online were recorded with the permission of the interviewees, in addition to taking notes of important points during the conversation and transcribed to facilitate the identification of keywords related to the analyzed topic.

Data analysis

Voss et al. (2002) recommend triangulating data and multiple sources of evidence for construct validity. Therefore, secondary data (e.g., websites and news) were used. All our research procedures were performed in three stages of the study, as described in our research protocol.

The stage of defining the maturity model aims to explore the existing digital maturity assessment models and define the one used to classify the studied company. This step is essential because there are several models of digital maturity. Therefore, it is important to understand them and proceed with the most appropriate way to apply them in Brazil's last-mile logistics.

To identify the company's digital maturity, the second stage of the interviews is to adapt the chosen model to the context of last-mile logistics, create the interview script (Appendix) and carry out conversations with employees. The interviews are semi-structured and carried out by the author, in person and remotely, with employees of the studied company who are involved with the last-mile area; the employees interviewed are the founder and CEO, the general manager of operations, the last-mile manager, the owner last-mile coordinator, the control tower supervisor, and the digital products area supervisor.

Based on the interviews, the third stage seeks to classify the last-mile area of the company under discussion within the chosen digital maturity model. The conclusion of the stages of this study will be relevant not only for the company that is the focus of the research but also for other companies in similar contexts, in addition to bringing the literature closer to the reality of the

Brazilian logistics market.

Maturity model to assess digital maturity at E-commerceCo

To assess the digital maturity more accurately for the last-mile area of an e-commerce logistics company, an adaptation in the functional areas of the Acatech model was carried out. Instead of the original five areas, we reduced it and changed it to three areas, namely: (i) logistics operations, responsible for the operation itself; (ii) control tower, responsible for the management and quality control of the operation; and (iii) digital products, responsible for the development of technological solutions that help the other two areas.

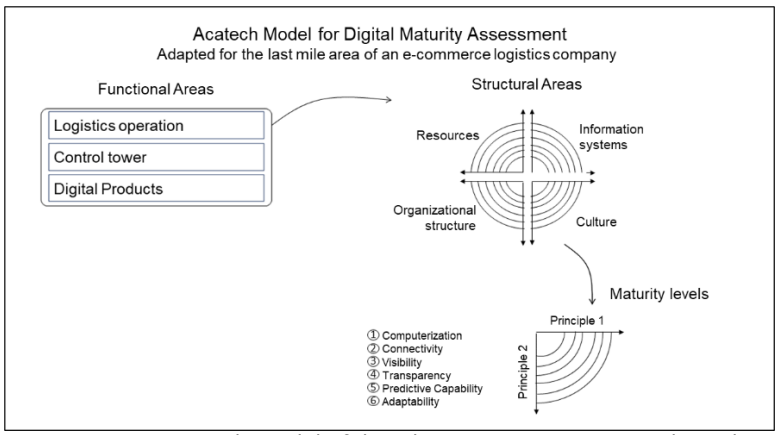

Figure 4 - Acatech Model of digital maturity assessment adapted
Source: Created by the author according to Schuh et al., 2020.

Although the functional areas were adapted, the maturity levels remained the original proposal. The first level, informatization, is the initial stage in which there are computers and devices, but they are not interconnected. The second is connectivity, in which devices are connected and generate data, but not all with the possibility of viewing and exchanging data in real time. The third level is visibility, defined by an increase in the number of sensors and other devices that generate data, which can be viewed in real-time, creating the company's digital shadow. According to Schuh et al. (2020), the company's digital shadow is essential for consolidating the level of visibility and advancing in the other levels of digital maturity.

The fourth level, transparency, is when technology helps in the diagnostic process, through data, about what is happening in the company. This technology shows the data and can also understand the reasons and root causes of problems and situations. At the fifth level of predictive capability, the company can project its digital shadow in different scenarios and understand the probability and outcome of each one, taking action in advance. In the last and sixth levels of adaptability, based on the prediction, the technology performs autonomous responses in situations that make sense. The different levels of digital maturity are shown in Figure 4.

RESULTS

Digital Maturity in Logistics Operations

The Logistics Operations is the area with the largest number of employees, having employees with administrative and operational functions; its responsibility is the effective delivery of the goods. Therefore, it is considered an essential part of the last-mile area. However, it is the least digitally mature area. Among the structural areas, all are at the level of connectivity, except for culture, which is at the level of transparency; therefore, the area as a whole is defined as a level of connectivity. The graph with the digital maturity of the Logistics Operations area is shown in Figure 5.

When analyzing the Resources, the area has a challenge due to the diversity of training of employees; as the last-mile manager reports, "The area of operation has employees with very different backgrounds, ages, origins, and expertise, so it is a challenge to create a standardized training plan, mainly in the digital part. While some have an academic background in technological areas, others have difficulty handling a smartphone." Nevertheless, many employees, especially

administrative ones, manipulate and analyze data to support decision-making, mainly by consulting the business intelligence (BI) tool that the company has. The characteristic that most limits the advance of digital maturity is the knowledge and processes carried out by the team involving the topic of cybersecurity, as reported by the last-mile manager himself: "(..) we are currently vulnerable to cyberattacks and data theft; unsafe behaviors, such as the sharing of passwords between employees, are frequent". These characteristics make the Resources area the level of connectivity.

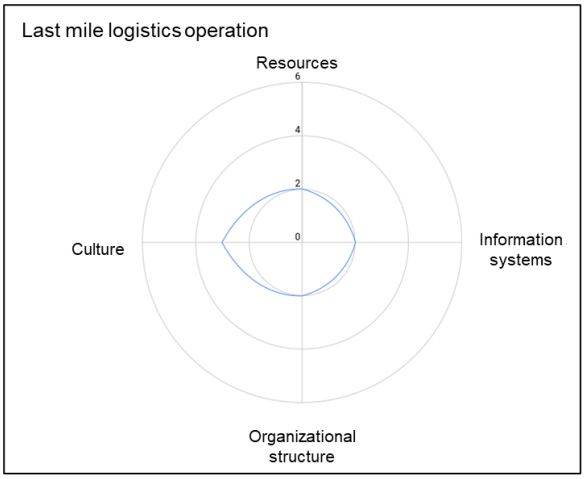

Figure 5 - Digital maturity in the area of Logistics Operations
Source: Created by the author.

Regarding the structural area of Information Systems, the operation uses two categories of systems. One of them is represented by the TMS (Transportation Management System), which consistently supports operational processes but delivers very little in information processing, availability of APIs, visualization, and data delivery. The other category is represented by the most modern systems, such as the delivery application and the data visualization platform, which can create and process large data. The e-commerce director corroborates this analysis by quoting "(...) to gain management and information processing capacity, we invest in technology to compensate for our TMS, which has limitations". Therefore, it is noted that the characteristics of the TMS make it impossible to create a digital shadow, an essential aspect for the consolidation of the area in terms of visibility, limiting the degree of connectivity.

When analyzing the Organizational Structure and Culture of the operations area, they are at the connectivity level (level 2) of digital maturity, coming close to the visibility level (level 3) in some topics. The internal organizational structure was designed to have agility in decision making, with much proximity and focus on the customer, as the last-mile manager reports: "(..) the operation has direct contact with the customer and has the autonomy to improve processes and make adjustments together with customers or suppliers; with that, we gain much agility". In addition, even with defects in the target system, the operation collaborates healthily with the network of suppliers, as stated by the general manager of operations: "(...) we have many suppliers in the last-mile operation; therefore the relationship with them is a part of our competitive differential; however, we still do not have a system of goals that encourages suppliers to act as we would like, generating alignment and performance problems".

Culture is the most mature point of the Logistics Operations, being at the visibility level (level 3). According to the general manager of operations, "(...), the operation is usually a hierarchical area with little innovation, but we try to change that by giving decision-making autonomy to employees and encouraging process improvement through not only formal projects but also spontaneously and with suggestions from employees". These characteristics also give employees a mindset of responsibility for executing change, not just reacting to it.

Digital Maturity in the control tower

The control tower area, since its conception, has the goal of analyzing data and helping the operation to improve its operational quality. Therefore, the team was assembled with people with digital capabilities. In addition, resources were allocated to help improve the technologies used by the area to advance in terms of operation visibility. That is why the Resources' structural area is quite advanced, mainly about providing digital capabilities. However, the communication efficiency

between the control tower and the other areas is inefficient, resulting in a connectivity maturity level (level 2) in Resources.

Analyzing the Information System structural area, we noticed a relevant difference in comparison to the others. Due to the investment received and the focus on specific points of the operation, from which there is real-time data on account of the application and other systems that circumvent the TMS, there is a digital shadow in the operation area of the control tower, which can, therefore, be set to a visibility level.

The Organizational Structure of the control tower is the least mature point because the employees are not able to act directly on the problems identified based on the analyses. This leads to the impossibility of being agile in actions and having difficulties in impacting the relevant indicators, which makes it difficult to set motivating goals. As the supervisor states, "at times, we demand a process to be carried out by the operation so that a certain result occurs, but the operation, even having the same goal, is trained to carry out a different process, generating frustration and exhaustion among the teams". Therefore, the Organizational Structure of the control tower is a level of informatization (level 1) in digital maturity.

In terms of culture, the control tower team is a level of visibility, according to the supervisor: "in the first days after the creation of the area, the company director talked to the team about the value of making mistakes, and that there would be no innovation without error, especially in a new area like ours; therefore, we have absorbed this characteristic in the culture since the beginning". In addition, the culture of continuous professional development stands out, as the general manager of operations recognizes: "because it is a new area, the team is discovering its performance, which encourages professional development not only with courses but also from interaction with different areas within the company". Bearing this in mind, the difference between a level three culture and a level one organizational structure is curious, showing the team has mature capabilities and resources. However, it is still not very mature in terms of organizational structure. Figure 6 shows the graph with the control tower assessments.

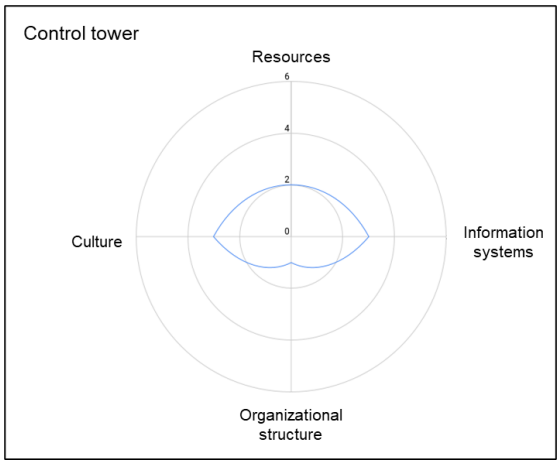

Figure 6 - Digital maturity of the control tower area
Source: Created by the author.

Digital Maturity in the Digital Products Area

The digital products area is responsible for the company's technological solutions and digital transformation. Internally, the area has a team focused on the last-mile. Due to its performance, the area naturally has a higher level of digital maturity than the rest, being the only one at the visibility level. The graph with the assessments of each structural area is in Figure 7.

Analyzing the Resources structural area, employees have an advanced degree of digital capacity to manipulate data, analyze systems and define requirements for technological improvements. In addition, the area has important relevance in managing information about the company. According to the Digital Products supervisor, "(...) the application, which is the area's responsibility, generates more than 70 thousand events per day, and they are all available in real-time in our BI tool, and we have a specialized team to help the rest of the company visualize information and perform analysis". In addition, the team has an agile work methodology. According to the general manager of operations, "the Digital Products area works in two-week periods, the sprints, in which they seek to complete tasks and deliver value with fast deliveries". Because of these characteristics, Resources have a level of visibility on the scale of the Acatech model.

On the other hand, the structural area of Information Systems for Digital Products has the same problem as the Logistics Operations area, in which the TMS used is old and has a series of characteristics that make it difficult to mature in the area; the most prominent being the lack of APIs for exchange data with other systems. However, the application, the delivery management system, and the data platform are quite advanced. Therefore, if the TMS did not have such limitations, this aspect would be at a visibility level (level 3), but currently, it is at a connectivity level (level 2).

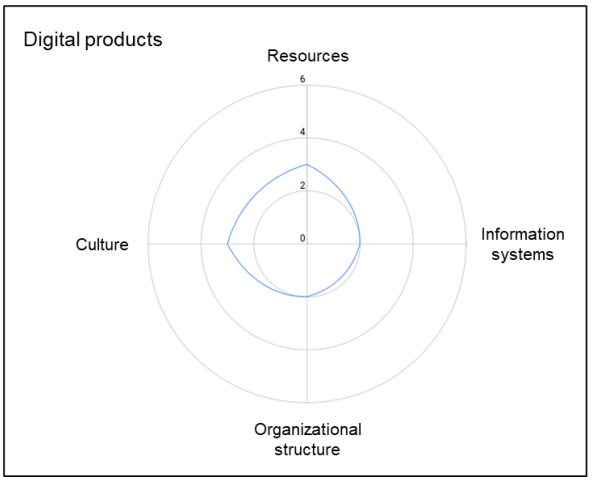

Figure 7 - Digital maturity of the digital products area
Source: Created by the author.

In terms of Organizational Structure, the area is divided into teams responsible for shared results with other areas, such as the Digital Products team focused on the last-mile to facilitate the interaction between specialists with a common goal or project. However, the area still needs to mature in the goals system, managing to create more assertive goals for actions involving digital products. According to the supervisor, "we still have not found the balance between the indicators of support of the systems, such as the number of errors in the updates, and the indicators of value delivery, such as cost reduction generated by a new functionality". Taking this into account, the level defined was connectivity (level 2), but almost advanced to that of visibility (level 3).

In the Culture structural area, the visibility level is mature. In line with the agile methodology, employees understand the value of error. There is openness to innovation, as stated by the executive director: "we encourage all areas to carry out experiments and try to innovate, but Digital Products is where we direct this behavior the most; we even ask them to help other areas to be more innovative".

Global Digital Maturity of the Last-mile Area

Because each division's digital maturity makes up the last-mile area, the global digital maturity level is connectivity (level 2). The lack of a real-time digital shadow is key for digital maturity to remain at level two. We highlight the TMS and its data processing limitations among the reasons for this lack. Replacing the system with one with more advanced technologies could make it possible to advance from the maturity to the visibility level in the structural area of Information Systems. In addition, especially in the control tower, the organizational structure needs to provide more autonomy so that employees who analyze the operation's data can carry out correction and improvement actions with greater agility.

Analyzing the Resources item, the team's knowledge, and daily attitudes related to cybersecurity is a point that restricts the company to the level of connectivity. Training performance and greater control of system access are two actions that would increase digital maturity. Figure 8 shows the graph with the levels of each structural area within the last-mile.

The last-mile area's strong point is culture, the only structural area at the visibility level. It happens because there is leadership with a democratic style, open communication, recognition of the value of error, openness to innovation, and a culture of protagonism in changes. According to the company's executive director, there is an effort to create an open, innovative, and technology-focused culture: "(...) there have already been programs in which employees joined in interdisciplinary groups and tested solutions to company problems; we performed a company-wide hackathon and participated in open innovation initiatives, where we shared our problems with

startups that could create solutions".

On the one hand, it is understood that the culture will be prepared to increase the maturity level quickly by advancing in the other limitations. However, on the other hand, a mature culture is not enough to advance in digital maturity. Culture, digital capability, and technical advance go hand in hand with creating a digitally mature company.

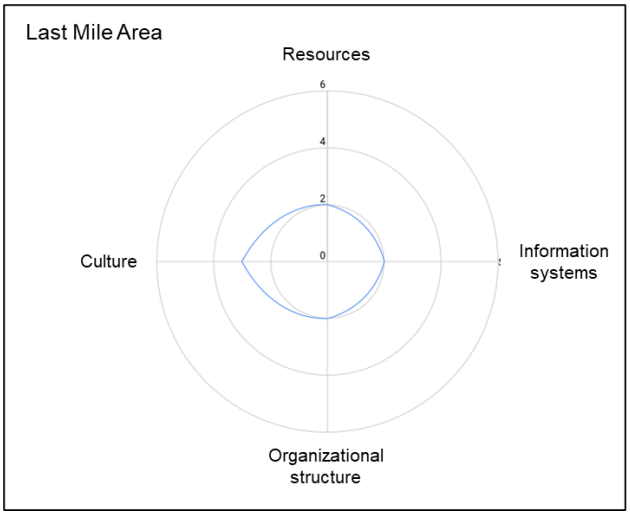

Figure 8 - Digital maturity of the last-mile area
Source: Created by the author.

DISCUSSION AND CONCLUSIONS

Digital transformation is a complex process that requires e-commerce logistics companies to have a defined strategy (Caetano, 2021; Correani et al., 2020; DHL Group, 2018). In this context, diagnosing the company using a digital maturity model is essential to success (Góes et al., 2019; Zapata et al., 2020). This article discussed the topic of digital transformation in last-mile logistics, adapted a digital maturity model to evaluate the niche better, and carried out the process of evaluating the digital maturity of a medium-sized Brazilian e-commerce logistics company through interviews with collaborators.

Boysen et al. (2021) reveal that existing last-mile research is particularly routing-focused and claim that the problem tasks beyond routing are a valid field for research. These authors noticed that there are huge challenges related to last-mile logistics in urban areas, a multitude of novel technological developments, and that more research about last-mile operations with major practical relevance must be developed. Dumanska et al. (2021) affirm in their study that COVID-19 crisis generated a considerable advance digital transformation in logistics operations, but also generated a lot of new challenges that companies should know how to realize these advances. In their study, the authors identified the principal tendencies of e-commerce, and digital transformation was considered. Finally, Herold et al. (2021) study not only shows the importance of enforcing digitalization in logistics operations but also provides insight for managers into the different adoption mechanisms and the associated actors that enact field-level changes, which can help to gain a better understanding of how to implement digital practices in their company. The authors affirm that research into digitalization is still in its infancy. Therefore, although there are studies in the literature that approach the last-mile and digitalization process, it is still missing the starting point for a digital transformation, which we discuss in this paper.

Consequently, our study had both practical and academic repercussions. Based on this article, the last-mile area of the studied company will be able to create a strategy to carry out a solid digital transformation, prioritizing the main aspects of improvement, such as the need for a more modern TMS and actions to increase cybersecurity, and understanding the current situation, such as the characteristic of the culture pillar being the most digitally mature. In academic terms, the study enriched the literature on models of digital maturity and digital transformation in logistics. However, the main academic result is the development of literature that combines the theoretical part of the topic with the practical part, which can serve as a reference for other companies in the e-commerce logistics sector to assess their digital maturity and compare common challenges and opportunities.

As a recommendation to continue and deepen the research on the topic, we suggest the performance of a digital maturity assessment in companies in the same sector. However, with

different sizes, areas within them, and countries, comparing the results and understanding whether lessons can be shared. In addition, we recommend carrying out case studies with different digital maturity models, analyzing the resulting diagnoses, and understanding the approaches and conclusions of each model.

REFERENCES

Alina, M. (2018), "Impact of Digitalization in Business World," *Revista de Management Comparat Internațional*, Vol. 19, No. 4, pp. 350–358.

Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009), "Developing Maturity Models for IT Management," *Business & Information Systems Engineering*, Vol. 1, No. 3, pp. 213–222. https://doi.org/10.1007/s12599-009-0044-5

Benbasat, I., Goldstein, D. K., & Mead, M. (1987), "The case research strategy in studies of information systems," *MIS Quarterly*, pp. 369-386.

Berghaus, S., & Back, A. (2016), "Stages in Digital Business Transformation: Results of an Empirical Maturity Study," *Mediterranean Conference on Information Systems (MCIS)*, Paper 22.

Bergmann, F. M., Wagner, S. M., & Winkenbach, M. (2020), "Integrating first-mile pickup and last-mile delivery on shared vehicle routes for efficient urban e-commerce distribution," *Transportation Research Part B: Methodological*, Vol. 131, pp. 26–62. https://doi.org/10.1016/j.trb.2019.09.013

Boysen, N., Fedtke, S., & Schwerdfeger, S. (2021), "Last-mile delivery concepts: a survey from an operational research perspective," *OR Spectrum*, Vol. 43, No. 1. https://doi.org/10.1007/s00291-020-00607-8

Carolis, A. D., Macchi, M., Negri, E., & Terzi, S. (2017, September), "A maturity model for assessing the digital readiness of manufacturing companies," In *IFIP International Conference on Advances in Production Management Systems*, pp. 13-20. Springer, Cham.

Dumanska, I., Hrytsyna, L., Kharun, O., & Matviiets, O. (2021), "E-commerce and m-commerce as global trends of international trade caused by the covid-19 pandemic," *WSEAS Transactions on Environment and Development*, Vol. 17, pp. 386–397. https://doi.org/10.37394/232015.2021.17.38

El País (2019), "A revolução logística chinesa que deixa a Amazon no chinelo," https://brasil.elpais.com/brasil/2019/07/05/economia/1562362005_685829.html

Felch, V., Asdecker, B., & Sucky, E. (2018), "Digitization in outbound logistics – Application of an Industry 4.0 Maturity Model for the Delivery Process," *OPUS*, pp. 113–128. https://doi.org/10.20378/irbo-54684

Gevaers, R. (2013), "Evaluation of innovations in B2C last-mile, B2C reverse & waste logistics," Universiteit Antwerpen, Faculteit Toegepaste Economische Wetenschappen.

Gevaers, R., Van de Voorde, E., & Vanelslander, T. (2009), "Characteristics of Innovations in Last-mile Logistics - Using Best Practices, Case Studies and Making the Link with Green and Sustainable Logistics," *Association for European Transport and Contributors*, October, pp. 1–8.

Góes, A., Rdorigues, A., & Potsch, F. (2019), "Análise de-modelos de maturidade e prontidão para a transformação digital," *UFRJ*.

Herold, D. M., Ćwiklicki, M., Pilch, K., & Mikl, J. (2021), "The emergence and adoption of digitalization in the logistics and supply chain industry: an institutional perspective," *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-09-2020-0382

Hossain, S., Hassan, S., & Karim, R. (2023), "Assessment of Critical Barriers to Industry 4.0 Adoption in Manufacturing Industries of Bangladesh: An ISM-Based Study," *Brazilian Journal of Operations & Production Management*, Vol. 20, No. 3, pp. 1797-1797.

Industry 4.0 How to navigate digitization of the manufacturing sector. (2015).

Kaji, J., Hurley, B., Devan, P., Khan, A., & Gangopadhyay, N. (2019), "Pivoting to digital maturity Seven capabilities central to digital transformation," https://www2.deloitte.com/content/dam/insights/us/articles/4955_Pivoting-to-digital-maturity/DI_Pivoting-to-digital-maturity.pdf

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2017), "Achieving Digital Maturity," *MIT Sloan Management Review and Deloitte University Press*, Summer, pp. 1–31. http://sloanreview.mit.edu/digital2017

Ko, S. Y., Cho, S. W., & Lee, C. (2018), "Pricing and collaboration in last-mile delivery services,"

Sustainability (Switzerland), Vol. 10, No. 12. https://doi.org/10.3390/su10124560

Kuusisto, M. (2017), "Organizational effects of digitalization: A literature review," *International Journal of Organization Theory and Behavior*, Vol. 20, No. 3, pp. 341–362.

Ladier, A. L., & Alpan, G. (2016), "Cross-docking operations: Current research versus industry practice," *Omega (United Kingdom)*, Vol. 62. https://doi.org/10.1016/j.omega.2015.09.006

Lahrmann, G., Marx, F., Winter, R., & Wortmann, F. (2011), "Business intelligence maturity: Development and evaluation of a theoretical model," *Proceedings of the Annual Hawaii International Conference on System Sciences*. https://doi.org/10.1109/HICSS.2011.90

Lichtblau, K., Stıch, V., Bertenrath, R., Blum, R., Bleider, M., & Millack, A. (2017), "IMPULS, Industry 4.0 readiness," *VDMA*.

Lim, S. F. W. T., Jin, X., & Srai, J. S. (2018), "Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models," *International Journal of Physical Distribution and Logistics Management (IJPDLM)*, Vol. 48, No. 3. https://doi.org/10.1108/IJPDLM-02-2017-0081

Maître, E., Sena, G. R., Chemli, Z., Chevalier, M., Dousset, B., Gitto, J. P., & Teste, O. (2022), "The investigation of an event-based approach to improve commodities supply chain management," *Brazilian Journal of Operations & Production Management*, Vol. 19, No. 2, pp. 1-19.

Melacini, M., Perotti, S., Rasini, M., & Tappia, E. (2018), "E-fulfilment and distribution in omni-channel retailing: a systematic literature review," *International Journal of Physical Distribution and Logistics Management (IJPDLM)*, Vol. 48, No. 4, pp. 391–414. https://doi.org/10.1108/IJPDLM-02-2017-0101

Melo, G. A. L. de, & Fernando, A. (2017), "As diferentes perspectivas da qualidade sobre nível de serviço na logística e os desafios do e-commerce," *Revista de Engenharia e Pesquisa Aplicada*, Vol. 2, No. 4. https://doi.org/10.25286/repa.v2i4.903

Moghadam, S. S., Ghomi, S. M. T. F., & Karimi, B. (2014), "Vehicle routing scheduling problem with cross docking and split deliveries," *Computers and Chemical Engineering*, Vol. 69. https://doi.org/10.1016/j.compchemeng.2014.06.015

Monteiro, L., Pinheiro, R., & Felinto, J.-R. R. (2021), "O Guia Definitivo sobre Loja Virtual," https://www.hostnet.com.br/blog/como-funciona-a-logistica-de-uma-loja-virtual-2/

Novaes, A. G. (2007), "Logística E Gerenciamento Da Cadeia De Distribuição," *Statewide Agricultural Land Use Baseline 2015*, Vol. 1, No. 2.

Petrovic, O., Harnisch, M. J., & Puchleitner, T. (2013), "Opportunities of mobile communication systems for applications in last-mile logistics," *2013 International Conference on Advanced Logistics and Transport, ICALT 2013*, pp. 354–359. https://doi.org/10.1109/ICAdLT.2013.6568484

Pöppelbuß, J., & Röglinger, M. (2011), "What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management," *19th European Conference on Information Systems, ECIS 2011*.

Roumboutsos, A., Kapros, S., & Vanelslander, T. (2014), "Green city logistics: Systems of Innovation to assess the potential of E-vehicles," *Research in Transportation Business and Management*, Vol. 11. https://doi.org/10.1016/j.rtbm.2014.06.005

Santiago da Costa, L., Pereira, L., & Akkari, A. (2018), "A Proposed Framework to Identify Digital Transformation Maturity in Small Industries," *Proceedings Name*, pp. 156. https://doi.org/10.3384/ecp1815630

Schuh, G., Anderl, R., Dumitrescu, R., & Krüger, A. (2020), "Industrie 4.0 Maturity Index."

Schumacher, A., Nemeth, T., & Sihn, W. (2019), "Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises," *Procedia Cirp*, Vol. 79, pp. 409-414.

Teichert, R. (2019), "Digital transformation maturity: A systematic review of literature," *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, Vol. 67, No. 6, pp. 1673–1687. https://doi.org/10.11118/actaun201967061673

Toy, J., Gesting, B., Ward, J., Noronha, J., & Bodenbenner, P. (2020), "The Logistics Trend Radar 5th Edition: Delivering insight today, creating value tomorrow."

Uehara, L. (2001), "Evolução do Desempenho Logístico no Varejo Virtual do Brasil," *ENEGEP*, 8. Link

Vakulenko, Y., Shams, P., Hellström, D., & Hjort, K. (2019), "Online retail experience and customer satisfaction: the mediating role of last-mile delivery," *International Review of Retail, Distribution*

and Consumer Research, Vol. 29, No. 3, pp. 306–320. https://doi.org/10.1080/09593969.2019.1598466

Van Belle, J., Valckenaers, P., & Cattrysse, D. (2012), "Cross-docking: State of the art," *Omega*, Vol. 40, No. 6, pp. 827–846. https://doi.org/10.1016/j.omega.2012.01.005

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002), "Pesquisa de casos na gestão de operações," *Revista Internacional de Operações e Gestão de Produção*, Vol. 22, Edição 2.

Wang, X., Shao, C., Yin, C., & Zhuge, C. (2018), "Exploring the influence of built environment on car ownership and use with a spatial multilevel model: A case study of Changchun, China," *International Journal of Environmental Research and Public Health*, Vol. 15, No. 9, p. 1868.

Westerman, G., Tannou, M., Bonnet, D., Ferraris, P., & McAfee, A. (2012), "The Digital Advantage: How Digital Leaders Outperform their Peers in Every Industry," *MIT Sloan Management Review*.

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Appendix A: Interview script to identify digital maturity based on the Acatech model

1. Resources

1.1 Providing digital capabilities

a) What is the autonomy level of employees to make decisions?

b) Can employees manipulate data, BI or Excel, without help? What is the percentage of employees who need to interpret data in the workday, approximately? Do you believe they do it well?

c) Do employees understand and take care when it comes to data security? Do they understand the importance of the topic?

1.2 Automated data collection through sensors

a) Are there cyber-physical systems technologies in the processes? Which ones?

b) Are there automated data collection technologies with sensors?

1.3 Decentralized data processing

a) Is there any technology that locally processes the captured data?

1.4 Efficient communication

a) How does communication between employees of the area work?

b) Is there any common place in which everyone access information?

c) Is there a lot of version conflict between documents and divergent information?

1.5 Task-focused interface

a) Regarding the main software used, are they focused on helping the employee to perform tasks? Is usability focused on getting the person to reach the expected result?

b) Regarding the arrangement of the workspaces and equipment involved, are they focused on helping the employee to perform tasks? Is usability focused on getting the person to reach the expected result?

2. Information Systems

2.1 Processing self-learning information

a) Does the area have a system that automates data analysis? Within the maturity levels, what is Diálogo's BI usage?

b) Is the data organized in a way that facilitates decision-making? How is the data visualization?

c) Is the interface showing data focused on the task the employee must perform?

2.2 Integration

a) Is there a single and true source of information, or is the information sometimes divergent between databases?

b) Is there data governance? Examples: approval processes, access control, understanding access levels, and security tests.

c) Is there a standardization in data formatting between different databases?

d) How is the company's data security? Are there security processes and barriers?

3. Organizational Structure

3.1 Internal organic organization

a) Does the organizational structure facilitate the communication of experts from different subjects?

b) When a project or work front occurs, is it ensured that the work is carried out by the people with the greatest ability, regardless of hierarchy or department?

c) Does the company have goal-oriented or result-oriented teams? If yes, how do they work?

d) How is the balance between decisions that need to be made centrally and those that need to be decentralized?

e) Is there a target system for employees?

f) If yes, in the previous question, how is the system? Is it motivating? Can it provide some security for employees to make mistakes?

g) How does the area create new products and services? Is there an agile mindset or methodology in the process?

3.2 Dynamic collaboration in value networks

a) When the company processes or creates services or products, is it focused on customer benefit? Do employees understand the market niche the company seeks to attack and what skills they need to serve them?

b) How does the company cooperate with the network of partners, suppliers, and customers? Is this way healthy and constructive for everyone?

c) How does the company protect its data when cooperating with suppliers and customers?

4. Culture

4.1 Social collaboration

a) What is the area's leadership style?

b) How is the communication between employees? Is it an open or closed style?

c) When systems are created or implemented, what is the role of different employees in creating or implementing this system? Do employees understand the system's value, or is it a requirement imposed on them?

4.2 Willness to change

a) How does the area recognize and understand the act of making mistakes? Do employees recognize the value of making mistakes?

b) Is the area open to innovation and change?

c) How much are decisions and learning based on data?

d) Is there a culture of continuous professional development in the company?

e) Do employees think they will lead the changes rather than just reacting to them? Or do they have a mindset of only reacting to change?

Appendix B: Models researched beyond the Acatech Model

1) Schumacher Model

In 2016, authors Schumacher, Erol, and Sihn proposed a maturity model based on experiences from strategic orientation workshops with several companies. According to the authors, companies have great difficulty understanding the general idea of Industry 4.0 and some of its particular concepts. On the one hand, they cannot strategically relate the benefits of Industry 4.0 to their business. However, on the other hand, companies face problems determining their current maturity level about Industry 4.0. As a result, these organizations fail to identify concrete fields of action, programs, and projects (Schumacher et al. 2016).

The model presents a roadmap with eight dimensions to analyze and four maturity levels. The eight dimensions are (1) Technology; (2) Products; (3) Customers and Partners; (4) Value creation processes; (5) Data and Information; (6) Corporate Standards; (7) Employees; and (8) Strategy and Leadership. To assess these dimensions, 65 maturity assessment items were proposed, consisting of questions to be answered describing a normal situation, with four possible answers, one for each maturity level. If the answer is on an item in items 3 or 4, the questionnaire also requires examples from the participant's work environment to increase the accuracy and reliability of the assessment.

After collecting all the data, the model uses an equation to calculate the company's maturity level. Each dimension is given a specific and different weight based on the organization's objectives. From calculating all the items, the company can see its strengths and weaknesses and where it should act next (Schumacher et al. 2019).

2) DREAMY Model

The Digital Readiness Assessment Maturity Model study (short for DREAMY), developed at the Politecnico di Milano, explicitly evaluates manufacturing and industrial companies' readiness for digital transformation. This maturity model chose to assess the digital readiness of manufacturing companies through four analysis dimensions: (1) Process; 2) Monitoring and Control, 3) Technology, and 4) Organization. These analysis dimensions were chosen mainly considering the DREAMY analysis units, which are relevant manufacturing processes. To this end, the study assesses:

How these processes are carried out (Process dimension),

The way these processes are monitored and controlled by evaluating the feedback received from their execution (Monitoring and Control dimension),

The technologies that support these processes (Technology dimension),

The organizational structures behind these processes (Organization dimension).

That is, not only the technologies used are considered.

Each dimension is evaluated via five key manufacturing processes: 1) design and engineering, 2) production management, 3) quality management, 4) maintenance management, and 5) logistics management. Thus, the maturity model provides a normative description of practices in each dimension and process, building an ordered order of practices.

The evaluation of the model takes the form of a questionnaire, with multiple questions for each process and dimension evaluated. Five response options are given for each question, each referring to a maturity level. DREAMY categorizes maturity levels as follows: initial; managed; defined; integrated and interoperable; digitally oriented (the lowest level of maturation being initial). From the responses, the model identifies where the organization is inserted in general and its strengths and weaknesses (De Carolis et al. 2017).

3) IMPULS Model

Another maturity model was also developed from the partnership between Industry and Academia. This study is so named because it was funded by the IMPULS Foundation of the German Engineering Federation (Lichtblau et al. 2017). The model has six dimensions:

1. Strategy and Organization
2. Smart Factory
3. Smart Operations
4. Smart Products
5. Data-driven services
6. Employees

Each of the six dimensions is ranked from 0 to 5 according to readiness level. Level 0 represents an outsider, or one not used to it when the organization has not done anything or very little to implement Industry 4.0 actions. Level 5, the highest, represents organizations that have successfully implemented Industry 4.0 tools. The study then classifies progress against the industry as Beginners (levels 0 to 1), apprentices (level 2), and Leaders (levels 3, 4, and 5). Like the other models presented, this analysis was made from questionnaires applied in mechanical engineering industries. The questionnaire did not cover industry types other than mechanics (Lichtblau et al. 2017).