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Application of the Industry 4.0 maturity model to industrial SME: 6 case studies

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Abstract The development of Industry 4.0 in industrial companies has led to the integration of physical objects, people, and smart machines in the production lines in the pursuit of efficient production processes with high added value. Here, small- and medium-sized companies have faced serious problems in developing and implementing Industry 4.0-related strategies and tools in their production processes. Thus, maturity models related to Industry 4.0 provide a strong perspective when it comes to guiding companies on their current state and path in implementing the appropriate strategies and tools. In the present paper, we show the results of the assessment procedure carried out by six SMEs from different industrial sectors located in the Basque Country (Spain); the assessment was carried out using the IMPULS maturity model with the aim of identifying steps to improve the implementation of Industry 4.0 techniques and strategies. The main finding underlines the need for SMEs to develop an Industry 4.0 strategy adapted to their industrial sector and the need to develop projects related to cybersecurity.

Keywords: Industry 4.0, Maturity model, Industrial SME

1 Introduction

With recent environmental, social, economic and technological advances, industrial companies face significant challenges. To overcome these challenges, companies increasingly need to use virtual and physical technologies that provide collaboration and rapid adaptation of their businesses and operations. The development of

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these concepts and technologies is usually included in the visionary concept of the Fourth Industrial Revolution (Industry 4.0) (Asadollahi-Yazdi *et al.*, 2020). The development of Industry 4.0 in industrial companies has served to integrate physical objects, human actors, intelligent machines and production lines while developing efficient production processes with high added value (Caiado *et al.*, 2021). In this sense, small- and medium-sized companies have serious problems developing and implementing the strategies and tools related to Industry 4.0 in their production processes (Mittal *et al.*, 2018). Therefore, new methods and tools are needed that can provide guidance and support to align business strategies and operations. In this situation, maturity models can provide insights into the current state of companies and the way forward to implement Industry 4.0 strategies (Wagire *et al.*, 2021) . Maturity models are commonly used to conceptualise and measure the maturity of an organisation or a process with respect to some specific objective state (Isikli *et al.*, 2018). In the present work, we show the results of evaluating the level of maturity using the IMPULS model (Schumacher *et al.*, 2016); the work was carried out with six SMEs from different industrial sectors located in the Basque Country of Spain; the aim was to help in identifying the steps that could improve their level of maturity in implementing Industry 4.0 strategies. The objective was to test the IMPULS tool in different industrial contexts on the current state of manufacturing companies and their Industry 4.0 strategies to find possible success factors. The practical objective was to help a company rigorously assess its own maturity for Industry 4.0 and reflect on the adequacy of its current strategies.

2 Methodology

The IMPULS maturity model was used as the methodological basis (Lichtblau *et al.*, 2015). The model can help assess a company's level of implementation of Industry 4.0. Hence, it is a very technology-oriented model.

Table 1: IMPULS model key dimensions and associated fields (Lichtblau et al., 2015)

Strategy and organisation	**Smart factory**	**Smart operations**
Strategy	Digital modelling	Cloud usage
Investments	Equipment infrastructure	IT security
Innovation management	Data usage in IT systems	Autonomous processes Information sharing
Smart products	**Data-driven services**	**Employees**
Data analytics in usage phase ICT add-on functionalities	Share of data used Share of revenues Data-driven services	Skill acquisition Employee skill sets

The maturity model was used to classify companies into three types depending on their level of implementation of the strategies and techniques related to Industry 4.0: 'newcomers', 'learners' and 'leaders'. This classification was based on the following six key dimensions of Industry 4.0—strategy and organisation, smart factory, smart operations, smart products, data-driven services and employees—that complement the 18 associated fields that show in Table 1; the analysis was conducted using a questionnaire. The fieldwork was carried out by means of an on-site visit to the facilities, where the general managers of the companies and their IT systems managers were interviewed.

3 Fieldwork

3.1 Description of companies

In this section, we present a descriptive summary of the most important characteristics and digitisation strategies of the participating companies to assess their state of maturity.

C1. EQUIPMENT GOODS: A company with 100 employees dedicated to the design and mass production of specific clamping, control and measuring tools. In the company, all staff have computers with internet access, invoicing is done online, and the ERP is connected to quality and stock control data. They use customer relationship management (CRM), work on a project basis, and data are analysed per customer. Files are shared via Dropbox. Databases are located on their own servers. They suffered a cyberattack, and they are working with an external security service. Suppliers have a portal and access to the system.

C2. MACHINE TOOL: A family company with 100 employees and two business activities: the construction of machinery and manufacture of precision tools for forging. It supplies automotive multinationals, is present in 25 countries and is considered one of the world's leading manufacturers in its sector. In the company, the use of devices is widespread, using both the cloud and its own servers. They have an internal specialist with external support, training is constant, especially in software, and the CRM is integrated into the ERP. The company has suffered cyberattacks. Their machines incorporate data collection systems and robotic elements. Radiofrequency technology is used to identify people. No information is shared with the supply chain. It has different lines connected to each other. Many commercial elements are used in a multiproject environment, so there is no exchange of information with suppliers.

C3. AUXILIARY OPERATIONS: A family company with 150 employees. The company specialises in auxiliary operations of heat treatment and coating of metal parts for all industrial sectors. They have computers associated with the machines

for data collection. They use ERP and CRM, and all information is in the cloud. There is an internal person with ICT knowledge, and ICT specialists are subcontracted for IT infrastructure maintenance (office software and web solutions). No ICT training is provided. Process data analysis is performed to improve the production process. They have suffered from a cyberattack in the past. The workers, controled the installations by mobile phone. They use sensors in the indicators. A radiofrequency system is in the barcodes of each order. The company has computers in the facilities where the information is collected. Supply chain information is shared with customers. Customers prioritise production via the intranet. Their facility suppliers have equipment monitoring and control systems in place. They have in-process data capture systems.

C4. TEXTILE: Family business with 170 employees dedicated to the design and manufacture of technical textile garments. In the company, all shared information is in the cloud, ERP, accounting information and so forth. They carry out database analysis with a specialised company, market prices, competition and trends. Three of their own people are dedicated to ICT support. They have a new server, and ERP is interconnected in all plants. The whole process is computer controlled. Traceability is determined by barcode and batch number. The phases and parameters of the manufacturing process are not computer controlled. They do not have automatic data collection systems in place. The facilities are not interconnected. CAD/CAM programming is used in manufacturing processes.

C5. AUTOMOTIVE AUXILIARY: A company with 100 employees that is a benchmark as a global supplier of metal automotive components for TIER 1 and TIER 2 companies. All shared information (process, ERP,) is in the cloud; they use DRIVE. There is an ICT manager, and most of the tasks related to ICT are outsourced. They have an ERP (BAAN) interconnected in all plants. They use customers' EDI platforms. They do not perform big data analysis. If they suffer from computer attacks, they block the network. Their facilities are not interconnected. Traceability is done by barcode. They have automatic handling and control systems (robots, visual). The monitoring of the process phases is computer controlled (PLL, CAPTOR, SKADA VIRTUAL). They have automatic data collection systems implemented (CAPTOR).

C6. BIOMEDICAL: Company with 65 employees. Technological company specialising in the automation of equipment for the hospital sector. Develops solutions to automate and control hospital processes. They use ERP, CRM and SAB. The information is not in the cloud. They have ICT specialists. They have the facilities connected via VPN with the facility provider. They use radio frequency identification technologies. An RFID system is used to ensure product traceability because it requires full traceability throughout the product's lifetime. Supply chain information is shared internally via Drive or Dropbox. It is also shared with suppliers and customers via Dropbox and Drive. They use email and WhatsApp for electronic transmission of supply chain information.

3.2 Results

Regarding the assessment based on the maturity model, Figure 1 shows that all companies are in a similar range of maturity with respect to Industry 4.0, between a scale of 2 and 3 (out of 5), here corresponding to the intermediate-level apprentices.

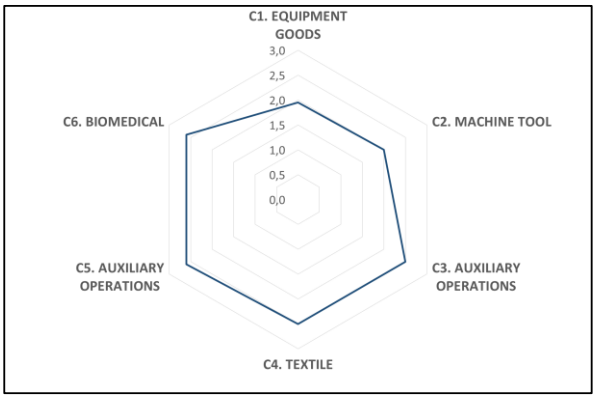

Figure 1: Total maturity level for each company

As shown in Figure 2, the categories of people, smart operations and smart factory stand out positively.

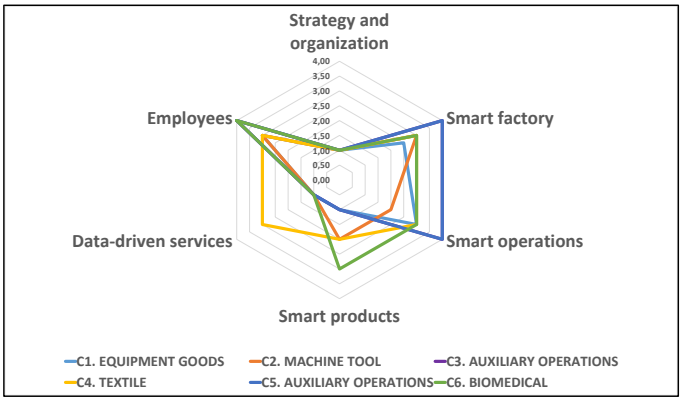

Figure 2: Comparison of the maturity level of each company in each category analysis

The areas of intelligent product and data-based service stand out in the biomedical, machine-tool and textile sectors, since these sectors have very specific needs in relation to the aforementioned areas. In the companies, a common aspect of improving refers to the lack of a written and defined strategy related to the development of Industry 4.0. However, all companies have included the definition of the Industry

4.0 strategy in their strategic plans. In addition, appropriate ICT security solutions are already in place and are being extended in all companies.

4 Conclusions

The study shows that each of the six companies analysed has specialised in the specific aspects required by the characteristics of the sector to which they belong. Their objective is not to reach the maximum level of Industry 4.0 maturity but to take advantage of the benefits offered by Industry 4.0 to generate competitive advantages in the specific areas of their sector. On the other hand, the IMPULS methodology has been validated as a tool for assessing the level of maturity in the field of Industry 4.0. Its application has allowed the analysed SMEs to identify opportunities for improvement in a simple way and adapt to the environment analysed. The study can serve as a basis for future studies.

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