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# A resource-based view on SMEs regarding the transition to more sophisticated stages of industry 4.0

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ABSTRACT

The integration of small and medium-sized enterprises (SMEs) within the concept Industry 4.0 represents one of its main challenges, as they play a vital part in industrial value chains that shall be digitized from suppliers to the end customer. However, what the implementation stages for Industry 4.0 in SMEs should be as well as the respective resources for achieving the next stage are scarcely understood. In response, this paper proposes a framework using a resource-based review for Industry 4.0 implementation according to the stage of development in SMEs, created between researchers, policy makers, and 354 manufacturing SMEs in the province of Gipuzkoa (Basque Country, Spain). The paper applies a mixed-method approach, combining qualitative (interviews) and quantitative elements (survey data). The results are used to develop a model with four stages of SMEs that are characterized by having distinct preconditions and conditions for Industry 4.0. Thereupon, the required measures to achieve the next stage of Industry 4.0 implementation are derived. This highlights Industry 4.0 for SMEs as a process with different stages toward achieving sustainable competitive advantage and offering insight into how the different resources operate. The high importance and advanced position regarding industrial value creation and SMEs in Gipuzkoa allows to generalize and transfer the findings to other European regions.

## 1. Introduction

While there is a general agreement that small and medium-sized enterprises (SMEs) face difficulties in implementing Industry 4.0, exactly which resources are required by SMEs in different implementation stages remains scarcely understood in extant literature (e.g., Mittal et al., 2019, 2018; Moeuf et al., 2020, 2018; Müller et al., 2021). SMEs, defined throughout the European Union as enterprises with a maximum turnover of 50 million € and with up to 250 employees, are of enormous importance for both the European and Basque economies (Eurostat, 2018; Eustat, 2018). This paper focuses on the case of one of the provinces of the Basque Country (Spain), Gipuzkoa, a highly industrialized territory within Europe where SMEs play a large role. Due to its high industrial share, innovation leadership and structural characteristics, a report for the European Commission states the Basque Country as having high structural similarity with leading European industrials regions such as Baden-Württemberg in Germany or Lombardia and Piemonte in Italy. This makes the results comparable and generalizable to such regions (Navarro et al., 2014). Further, in Gipuzkoa, one of the three provinces of the Basque country regarded in this study, the industrial share in value added (27.8%) is even higher than in the Basque country (23.9%) and significantly higher than in Spain (16.1%) or the EU 27 countries (19.7%) (Eurostat, 2018; Eustat, 2018; Navarro & Vázquez, 2021).

The great importance of industrial SMEs means that beyond economic rationales, the successful integration of SMEs into Industry 4.0 is also a relevant social challenge and thus, specific policies and programs should be designed accordingly (Müller & Voigt, 2018). The problem statement that guides this paper is that, unless more attention is paid in the literature to integrating and supporting SMEs within Industry 4.0, many of these enterprises might be left out of this new paradigm (Bär et al., 2018; Müller et al., 2018). While it is true that general challenges of Industry 4.0 in SMEs are comparably better understood (e.g., Moeuf et al., 2018; 2020), the implementation stages of Industry 4.0 for SMEs and which resources are required to achieve the next stage has scarcely been investigated to date (Arcidiacono et al., 2019; Ghobakhloo, 2018;

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Mittal et al., 2018, 2019). In response, this paper takes a resource-based view (RBV) to address this research gap, aiming to contribute to a better understanding of the implementation stages and the respective resources acting as conditions in each stage by answering the following research question:

What are the required resources that explain the transition between the stages of Industry 4.0 development in manufacturing SMEs?

Based on taking an RBV, the paper's contribution is a framework for building an inclusive Industry 4.0, integrating company representatives, policy makers and researchers to help SMEs in Gipuzkoa. This framework considers the inclusion of SMEs in Industry 4.0 as a progressive, potentially multi-step process toward more sophisticated applications of Industry 4.0. For this reason, it defines a series of stages and the resources that are determinant in each stage. By developing the resources acting as conditions in each stage, SMEs generate the resources needed to evolve into the next stage. The framework presented is inclusive because it assumes that the process has already started with the use of less sophisticated technologies, e.g., enterprise resource planning (ERP), which certain frameworks do not consider as part of Industry 4.0, but are actually not even state of the art in some manufacturing SMEs today. In this way, even SMEs with less sophisticated technologies can anchor into this process and evolve. Further, the paper shows how the analytical framework has been used to study and support 354 SMEs in Gipuzkoa.

The remainder of this manuscript is organized as follows: section 2 presents the theoretical background. Sections 3 and 4 describe the method and results of the empirical research into 354 SMEs in Gipuzkoa. The results are discussed in section 5 and the conclusions are presented in section 6, along with theoretical and managerial implications and suggestions for future research.

## 2. Theoretical background

### 2.1. Industry 4.0

The term Industry 4.0 refers to the concept of a fourth industrial revolution. It was originated in the German government's strategy for reinforcing the competitiveness of its manufacturing industry and first appeared in 2011, when it was introduced at the Hanover Fair (Kagermann et al., 2013; Lasi et al., 2014). In this paper, we define Industry 4.0 following the initial concept of the German government as published by Kagermann et al. (2013): The main technological foundation of Industry 4.0 is the integration of cyber-physical systems (CPS) based on the concept of the Internet of Things (IoT) into manufacturing. It aims to develop intelligent, self-regulating, and interconnected industrial value creation. CPS allow data to be collected by products, production facilities and customers across the entire value chain, which is made possible thanks to the interconnection via the IoT (Kagermann et al., 2013; Lasi et al., 2014). It is these properties of CPS and the IoT that enable the central characteristics of Industry 4.0: horizontal and vertical integration, i.e., digitally enabled integration of company functions, and digitally enabled integration across the value chain, from the customer to the other end of the value chain, which are often represented by SMEs (Kagermann et al., 2013; Lasi et al., 2014; Ghobakhloo, 2018; Müller et al., 2018).

These technological foundations allow for more efficient, flexible, and resilient industrial value creation, improving operational effectiveness and, therefore, the competitiveness of industry (Kagermann et al., 2013; Lasi et al., 2014): Besides these operational benefits, strategic potentials are also expected, such as entirely digitized, connected, smart, and decentralized value chains that contribute to ecological and social targets. Moreover, it opens the door for providing new services and developing other business models. These are based on data-driven value propositions through data availability across the value chain and data analytics (Frank et al., 2019; Kagermann et al., 2013; Müller et al., 2018, 2021).

However, to enable the full potential of Industry 4.0, data availability and data exchange across the supply chain, as well as further technological enablers must first be achieved. There are several barriers of different origin when it comes to implementing Industry 4.0 and they are especially crucial for SMEs (Müller et al., 2021; Raj et al., 2019), as described in the next section. In general, SMEs must be integrated within the concept of Industry 4.0, given the role they play in industrial value creation (Müller et al., 2018; Moeuf et al., 2018, 2020).

### 2.2. Industry 4.0 in SMEs

There is extant research on Industry 4.0 stressing the fact that it is often harder for SMEs to attain the potential benefits of Industry 4.0 than it is for large enterprises (Horváth & Szabó, 2019; Müller et al., 2018). In contrast to their larger counterparts, SMEs often do not recognize or even attempt to understand the strategic benefits that could be achieved if they implemented Industry 4.0. This is due to limited resources that often and lacking strategy toward Industry 4.0 (Horváth & Szabó, 2019; Masood & Sonntag, 2020; Moeuf et al., 2018, 2020; Sahi et al., 2020; Stentoft et al., 2020). Other insufficient resources include niche-oriented business models and innovation management approaches that are often much more focused on operational adjustments rather than considering new forms of value creation (Müller et al., 2018, 2021; Somohano-Rodríguez et al., 2020). Additionally, little or no automation in value creation processes as well as non-standardized processes in SMEs are found to hamper the implementation of Industry 4.0 (Müller et al., 2018; Stentoft et al., 2020).

Furthermore, the transition toward Industry 4.0 requires a greater change in terms of removing functional silos, change management, supportive culture, supply chain integration, and data transparency across the entire value chain. All these factors prove to be especially challenging for SMEs due to extant logics regarding value creation and their extant business models (Ghobakhloo, 2018; Moeuf et al., 2018, 2020, 2020; Müller et al., 2018, 2020). This leads to fear toward change and job losses, which needs adequate change management processes and culture that are often missing in SMEs (Cimini et al., 2020; Khanzode et al., 2020; Raj et al., 2019). Likewise, the low level of standardization and digitalization, and smaller production series combined with less automated production equipment or limited access to financial resources and knowledge can hamper Industry 4.0 implementation in SMEs (Horváth & Szabó, 2019; Müller et al., 2018). A detailed overview of the respective resources, divided into preconditions and conditions of Industry 4.0, is developed in section 3.1.

Policy makers and industry associations are concerned that SMEs are being left behind in Industry 4.0 implementation, and there are no clear frameworks or guidelines to support them in implementing Industry 4.0 relating to the respective resources (Khanzode et al., 2020; Mittal et al., 2018, 2019). Indeed, the development of Industry 4.0 can be brought to a standstill if SMEs, which are the bulk of the European production industry, are not included in it (Müller et al., 2018; Moeuf et al., 2018). Furthermore, most industrial value chains are largely dependent on SMEs as suppliers, which means that they need to be included in horizontal and vertical integration, representing key pillars of Industry 4.0 (Bär et al., 2018; Müller et al., 2021).

### 2.3. Resource-based view and research gap

According to RBV, organizations can improve their competitive position, e.g., with regard to costs, quality, or further factors for differentiation, if they possess and exploit resources and capabilities that are valuable, rare, inimitable, and non-substitutable (Barney, 2001; Newbert, 2008). The RBV aims to understand the relationships between different resources and how resources can be combined to maintain competitive advantage (Barney, 2001; Peteraf, 1993). Therefore, this paper regards RBV as a suitable theoretical perspective to investigate the implementation levels of Industry 4.0 in SMEs and how different resources interplay to achieve the next level.

Research on Industry 4.0 has identified the lack of experience in SMEs, especially in terms of a limited number of roadmaps, maturity models, frameworks and readiness assessments which reflect the specific resources of SMEs (Mittal et al., 2018; Müller et al., 2021), targeted aspects for Industry 4.0 implementation, and implementation patterns (Frank et al., 2019). In contrast to extant publications, this paper goes beyond developing a framework of conditions in SMEs regarding Industry 4.0. It further includes RBV as a theoretical perspective and presents the results of a process that has lasted for more than two years, in which policy makers, development agencies, and SMEs themselves have been part of an implementation approach.

In doing so, this paper contributes to fill the following research gaps in extant literature:

1) Include an RBV within an implementation model of Industry 4.0, as Industry 4.0 in general has scarcely been analyzed from the perspective of RBV so far (e.g., Salam, 2019).
2) Improve the way SMEs' requirements are integrated into policy for Industry 4.0 by developing a model of implementation stages toward Industry 4.0 that begin before extant maturity models, representing the development stage of many SMEs that are currently left out of the process (e.g., Mittal et al., 2018; Müller et al., 2018).
3) Develop a long-term perspective with development stages for Industry 4.0 in SMEs in contrast to observations that can only report from a single point of time (e.g., Frank et al., 2019; Müller et al., 2018).

In sum, the paper aims to show how specific resources are combined in different development stages of SMEs toward Industry 4.0, i.e., how different resources relevant for Industry 4.0 implementation lead to sustainable competitive advantage through Industry 4.0 implementation. It further connects the RBV with a long-term implementation plan comprised of different stages, highlighting the requirement to combine resources by a firm strategy and adequate leadership (Bhandari et al., 2020).

## 3. Methodology

Given that the topic of Industry 4.0 implementation in SMEs represents a novel and emerging phenomenon that shall be explored in its real-life environment, a case study approach was chosen (Yin, 2017). The case, the region of Gipuzkoa within the Basque Country in Spain, is explained in section 3.1. The case study is built upon a two-stage process: The first stage is a series of workshops where researchers, policy makers, and development agencies discuss and condense the experiences and challenges of SMEs with regard to Industry 4.0. This process is described in section 3.2. Thereupon, the research methods of the second stage are defined in order to test, quantify and deepen the results of the first stage. The second stage consists of a mixed-method approach described in section 3.3, combining qualitative (section 3.4), and quantitative research (section 3.5) (Bryman, 2006; Venkatesh et al., 2016).

### 3.1. Case description

The Basque Country is one of the most industrialized regions in Europe. The industry sectors of automotive, basic metals and metal products, machinery and equipment, and electrical and electronic equipment, representing the majority of firms regarded in this study, constantly account for about 50% of jobs. This is about twice than it is in the rest of Spain. Further, SMEs constantly contributed almost 70% to the gross domestic product (GDP) in the Basque Country over recent years. In Spain, this number is around 60%, while in the EU, SMEs contributed around 50% of the GDP over the last years (Eustat, 2018; Navarro et al., 2014; Navarro & Vázquez, 2021).

According to a structural analysis for the European Commission, the Basque Country is comparable and results are transferable to leading industrial regions in Europe. In Spain, it is the only strong innovator region besides the greater Madrid region (European Innovation Scoreboard, 2021). Examples for structurally comparable regions are Baden-Württemberg in Germany or Piemonte and Lombardia in Italy (Navarro et al., 2014). Those are regions well-known for their industrial strength and innovativeness, headquartering firms like Bosch, Daimler, or Fiat. Further comparable regions in Europe include Lower Austria with several automotive industry clusters or Wales with, e.g., automotive and aerospace industry clusters (Navarro et al., 2014). Based on this structural analysis by the European Commission, we claim that the findings are generalizable and transferrable to other leading industrial regions throughout Europe.

Moreover, the Basque Country has been considered an interesting example for the analysis of industrial policy (Navarro & Sabalza, 2016). Even in periods when these types of policies were unpopular in comparison with develop service industries, the regional government has made an intensive effort to sustain strong industrial policy since it was established in 1980 (Magro et al., 2020; Morgan, 2016). The provincial councils and county development agencies are, together with the Basque Government, part of the public administration institutions that support such industrial policy. Because SMEs are the bulk of this industrial activity, they have been explicitly considered in the policies by the regional government. Indeed, the integration of Industry 4.0 in SMEs is one of the main challenges for industrial transition in this region, as it represents a general challenge of Industry 4.0 (Moeuf et al., 2018, 2020; Müller et al., 2018). These features make the case suitable to answer the research question and generate knowledge about Industry 4.0 in SMEs which is more nuanced than extant knowledge. This is as this paper presents the results of a process that was developed between policy makers, development agencies and SMEs over more than two years.

Gipuzkoa, one of the three regions within the Basque Country, has an even higher industrial share in value added (27.8%). This industrial share is higher than in the Basque country (23.9%) and significantly higher than in Spain (16.1%) and the EU 27 countries (19.7%) (Eurostat, 2018; Eustat, 2018; Navarro & Vázquez, 2021). In Gipuzkoa, the subgroup of manufacturing SMEs with between 20 and 99 employees alone represents 23.7% of all manufacturing firms. Investigating SMEs with between 20 and 99 employees means that very small firms that often struggle with Industry 4.0 due to lacking process standardization as a result of workshop environments are left out of the analysis. In addition, given that larger SMEs often do not share the typical characteristics of small firms with regard to Industry 4.0, the entire research design can therefore be more defined (Müller et al., 2018).

### 3.2. Questionnaire development

In this case study, focus groups with policy makers of the Provincial Council of Gipuzkoa and county development agencies of this territory made it possible to define the methodology used for interviewing the firms. These focus groups were moderated by the authors of this paper, which were the main point of contact with the 354 SMEs that participated in the research process. The shared goal was to analyze the situation of SMEs regarding Industry 4.0 in order to inform policy programs on how to help them onto the Industry 4.0 path. The long-term relationship between these agencies and SMEs explains the high response rate of 70% referred to in section 3.2.

The meaning of Industry 4.0, the list of 4.0 technologies considered, the analytical framework described in section 4 and corresponding interview guidelines and questionnaires were co-defined through participation in focus groups. At these workshops, researchers contributed their academic knowledge on Industry 4.0 and on the ongoing analysis, policy makers from the Provincial Council contributed their knowledge on the policy process, and the county development agency staff contributed their knowledge on the situation of SMEs. Table 1 summarizes the dates, participants, issues addressed, and results and

**Table 1**
Focus group workshops.

| Date of the workshop | Participants | Issues addressed | Results and further actions |
|---|---|---|---|
| May 12, 2017 | 4 researchers.<br>3 policy makers from the Provincial Council.<br>17 policy makers from county development agencies. | • Objectives of the process for supporting SMEs in Industry 4.0.<br>• Meaning of Industry 4.0.<br>• Preconditions and conditions for the transition to Industry 4.0.<br>• Role of agencies within the innovation system when supporting SMEs in Industry 4.0.<br>• Methodology for interviewing SMEs; group discussion to make contributions.<br>• Presentation by agencies of projects and experiences on 4.0 and SMEs. | (Researchers) Drawing up of the interview guidelines.<br>(Agencies) Identification of the challenges that agencies will face when conducting the interviews. |
| June 6, 2017 | 5 researchers.<br>3 policy makers from the Provincial Council.<br>13 policy makers from county development agencies. | • Defining Industry 4.0 in the project.<br>• List of 4.0 technologies.<br>• Meaning of servitization.<br>• Examples of servitization processes in SMEs.<br>• Identifying other agents in the innovation system for supporting Industry 4.0 transition on SMEs. | (Researchers) Drawing up of a new version of the interview guidelines.<br>(Researchers) Definition of the role of agencies within the innovation system when supporting SMEs in Industry 4.0. |
| September 9, 2017 | 4 researchers.<br>5 policy makers from the Provincial Council.<br>13 policy makers from county development agencies.<br>2 policy makers from the Basque regional Government. | • Definitive interview guidelines (including issues addressed in the previous workshop).<br>• Database to gather the information collected in the interviews.<br>• Presentation by policy makers of public programs (Provincial Council and Basque Government) supporting Industry 4.0 in SMEs. | (Researchers) Drawing up of a new version of the interview guidelines.<br>(Agencies) Pilot testing of the methodology used for interviewing 28 SMEs.<br>(Researchers) Analysis of information gathered in the database. |
| November 2, 2017 | 4 researchers.<br>4 policy makers from the Provincial Council.<br>13 policy makers from county development agencies.<br>2 policy makers from the Basque Innovation Agency (Innobasque).<br>2 policy makers from the Basque Vocational Education and Training Innovation Agency (Tknika). | • Results of pilot interviews in 28 SMEs: discussion on changes in the guidelines, questionnaires and the database.<br>• Presentations by Tknika and Innobasque, complementary to county development agencies in supporting Industry 4.0 in SMEs. | (Researchers) Publication of the definitive interview guidelines and database.<br>Agencies) Visits and interviews with SMEs.<br>(Researchers) Analysis of information gathered in the database. |
| February 15, 2018 | 3 researchers.<br>3 policy makers from the Provincial Council.<br>12 policy makers from county development agencies.<br>2 GAIA associates (ICT Cluster Association). | • Challenges, beyond the methodological approach, for supporting SMEs' transition to Industry 4.0.<br>• Presentation by GAIA, complementary to county development agencies in supporting Industry 4.0 in SMEs. | (Agencies) Visits and interviews with SMEs.<br>(Researchers) Analysis of information gathered in the database. |
| May 3, 2018 | 5 researchers.<br>3 policy makers from the Provincial Council.<br>13 policy makers from county development agencies. | • Preliminary analysis by researchers of the results from the information gathered in the database. Agreement on the objectives of future policy programs to support SMEs' transition to Industry 4.0. | (Agencies) Visits and interviews with SMEs.<br>(Researchers) Analysis of information gathered in the database,<br>(Provincial Council) Design of the new policy program. |
| June 28, 2018 | 4 researchers.<br>5 policy makers from the Provincial Council.<br>13 policy makers from county development agencies. | • Analysis of results by researchers.<br>• Agreement on the objectives, principles and conditions of a new policy program.<br>• Agreement on the objectives of a new research project on Industry 4.0 and SMEs. | |

further actions in each of these focus group workshops.

During the workshops, the contents of these meetings and subsequent discussions were transcribed by several researchers individually. After the workshops, the results of the dialogue among participants were condensed and systematized using a qualitative content analysis with an inductive research approach. Any deviations between the different researchers that made the transcriptions of the workshops were discussed until agreement was reached (Bryman, 2006; Gioia et al., 2013). Subsequently, the results of this process were shared with participants and conferred in the next workshops until their consent was given. Further, the results were compared with extant literature and possible missing aspects were discussed with workshop participants about whether those should also be included. Qualitative content analysis was also applied to examine the interviews described in section 3.2.

As a result of this process, two types of resources for the implementation of Industry 4.0 were identified. The first category of resources, which is based on the previously quoted studies, was directly defined together with the experts in Industry 4.0 and was named *conditions for Industry 4.0*. These conditions would help analyze the situation of firms which have favorable settings for implementing Industry 4.0 straightaway. The second type of resources was aimed at firms in an earlier stage of their development and was named *preconditions*. These preconditions refer to the basic requirements needed for firm competitiveness, mainly related to the modernization of firms in organizational, product, and process issues. The decision to also work on preconditions makes Industry 4.0 accessible to more firms and is an inclusive feature of the methodology presented.

When considering the technologies to be addressed within Industry 4.0, inclusiveness was complemented in the definition of resources. The list of technologies was also inspired by the literature and developed between policy makers and researchers. It was decided that, although some very basic technologies are not considered by the literature as belonging to Industry 4.0, they would be included here so that a larger number of firms could see Industry 4.0 as an attainable objective. That is, many SMEs are still far from needing high-tech approaches straightaway, but rather require a long-term, stepwise implementation plan (Mittal et al., 2018, 2019; Moeuf et al., 2018, 2020; Müller et al., 2018). The rationale behind this decision was that there might be firms which, by integrating less sophisticated technologies, could improve their preconditions and conditions, and therefore could be considered as candidates to adopt technologies they might not have been able to implement before. This was the reason why technologies, such as ERP, was included in the program's list of technologies, which was defined and divided into two groups: The first group is comprised of technologies that are typical in large enterprises today, but which represent a prerequisite for Industry 4.0 that often has not yet been achieved by many SMEs (Müller et al., 2018): ERP systems and computerized numerical control (CNC) for processes and production equipment. The second group includes technologies that are at the core of Industry 4.0 when applied in horizontal and vertical integration (Kagermann et al., 2013): IoT, Integration of Sensors and Advanced Metrology, Cloud Computing, Data Analytics and Big Data Analysis, Cybersecurity, Modelling and Simulation, as well as Additive Manufacturing. These technologies mentioned represent the majority of technologies regarded in extant maturity models in managerial practice toward Industry 4.0 (Mittal et al., 2018; Wagire et al., 2020). The conditions and preconditions for Industry 4.0, which were defined as resources in the analytical framework are synthetized in Table 2.

In order to comply with the characteristics of resources within the RBV, valuable, rare, inimitable, and non-substitutable (Barney, 2001), the workshops between policy makers, country development agencies, SMEs, and further stakeholders were designed to ensure that the resources defined fulfilled the above-named criteria. Further, as in addition to the original four characteristics of resources, Barney and Hesterly (2010) extended added a fifth characteristic, organized resources, we ensured this criteria as well as reflecting its importance in the existence of an Industry 4.0 implementation plan, as described in section 4. All criteria for resources were further ensured in the conducted follow-up interviews and workshops after the qualitative and quantitative investigations. In conjunction, we argue that the combination of the valuable, rare, inimitable, and non-substitutable resources that are organized leads to a sustainable competitive advantage through the implementation of Industry 4.0.

### 3.3. Empirical approach

Based on the results of the workshops described in the previous section, an empirical, interview and survey-based research was conducted. Through this mixed-method approach, the benefits of qualitative and quantitative research could be combined, thus reducing the bias of both methods (Bryman, 2006). While the qualitative approach serves to derive constructs and requirements of SMEs for certain development stages toward SMEs, the quantitative approach shows relationships between the identified constructs, especially separating those between different development stages.

The mixed-method approach consists of a sequential research design, consisting of two steps (Venkatesh et al., 2016). The first step started with a qualitative investigation where in-depth expert interviews were conducted. These interviews served to a) classify the respective SME into groups so as to distribute the appropriate questionnaire in the quantitative investigation and b) gain greater insights and expert opinions from SMEs in the respective groups. Relating to the research question "*What are the required resources that explain the transition between the*

**Table 2**
Resources as preconditions and conditions of Industry 4.0 in SMEs.

| | Resource | Description | Exemplary references |
|---|---|---|---|
| **Preconditions for Industry 4.0** | Products | Helps SMEs to understand the effects or the potential of Industry 4.0 in the case of being a process developer or having their own product. | Arcidiacono et al., 2019; Horváth & Szabó, 2019 |
| | Innovation | Assesses SMEs' resources, capabilities, and focus on innovation (product, process, organizational or commercial). | Müller et al., 2018, 2021 |
| | Internationalization | Evaluates the firm's level of internationalization by analyzing its export turnover and capability to establish foreign trade networks and to develop an internationalization plan. | Horváth & Szabó, 2019; Mittal et al., 2018, 2019 |
| | Alliances | Assesses the existence of cooperation within the value chain or with other actors of the territorial innovation system. | Müller et al., 2018, 2021 |
| | Skills Plan | Determines whether the SME has an employee development plan for improving the skills and competencies of staff | Birkel et al., 2019; Matt et al., 2020 |
| | Skills Management | Evaluates whether the management model is consistent with the skills development plan and makes the most of staff capacities through participation in decision making | Matt et al., 2020 |
| | Strategy | Determines if the firm has designed a strategy for the future as well as a strategic plan through which it expects to make its transition. | Horváth & Szabó, 2019; Sahi et al., 2020 |
| | Leadership | Examines whether the SME has shifted to a leadership model in which managers take decisions and risks, anticipate problems, and encourage staff to participate. | Birkel et al., 2019; Moeuf et al., 2018, 2020 |
| | Finances | Assesses the viability of the strategic plan in terms of allocating resources and financial management capabilities. | Moeuf et al., 2018, 2020; Müller et al., 2018, 2021 |
| **Conditions for Industry 4.0** | Market | Determines to what extent the sector the SME operates in is one where there is pressure or possibilities to advance in the | Müller et al., 2018, 2021; Moeuf et al., 2018, 2020 |

(*continued on next page*)

**Table 2** (*continued*)

| | Resource | Description | Exemplary references |
|---|---|---|---|
| | | transition to Industry 4.0. | |
| | Competitors | Identifies where the SME is positioned in the value chain and how its relationship with other (often bigger and client, but also competitor) firms in the chain can affect Industry 4.0. | Bär et al., 2018; Birkel et al., 2019 |
| | Servitization | Addresses to what extent manufacturing and service provision are connected, and opportunities are envisaged in terms of servitization and service-based business models. | Frank et al., 2019; Müller et al., 2018, 2021 |
| | Efficiency | Evaluates the profitability of potential investments of the SME in Industry 4.0. | Birkel et al., 2019; Moeuf et al., 2018, 2020 |
| | Strategy | Explores whether the "Industry 4.0 plan" is aligned with the strategic thinking of the firm, which requires top management involvement and a holistic approach. | Moeuf et al., 2018, 2020; Sahi et al., 2020 |
| | Qualified staff | Assesses the qualification level of staff or the possibility of furthering qualifications to face Industry 4.0-related challenges. | Matt et al., 2020; Moeuf et al., 2018, 2020 |
| | Investments | Evaluates the potential of the SME to allocate resources to Industry 4.0-related investments. | Müller et al., 2018, 2021 |
| | Alliances | Determines the extent to which the SME is developing Industry 4.0-oriented cooperation with other SMEs, in the value chain with customers and suppliers or through alliances with actors from the innovation system. | Bär et al., 2018; Müller et al., 2018, 2021 |
| | Organization | Examines whether the managerial and organizational models are adapted to the requirements of Industry 4.0. | Moeuf et al., 2018, 2020; Sahi et al., 2020 |
| | Infrastructure | Assesses the availability of high-speed network in the area where the firm is located. | Birkel et al., 2019; Mittal et al., 2018; 2019 |

*stages of Industry 4.0 development in manufacturing SMEs?*", *different* groups of SMEs in distinct stages of Industry 4.0 implementation are derived in an initial, qualitative approach that further serves to gain expert opinions and explore other topics that have not been considered in the literature or in the initial workshops. Subsequently, the characteristics and distinct configuration of resources between the stages are defined and quantified in a second, quantitative stage (Creswell, 2013; Tashakkori & Teddlie, 2010).

Depending on their answers, a specific quantitative survey was given to the respective respondent in the second step, which is shown in the Appendix. These surveys serve to quantify the resources as preconditions and conditions presented in Table 2, and also to differentiate between the five groups of SMEs defined in the following.

### 3.4. Qualitative investigation and definition of SME categories

In the first step, 506 SMEs with between 20 and 99 employees were contacted, the response rate being 70%. Thus, the final sample size consisted of 354 SMEs. The list of firms came from the Basque Directory of Economic Activities managed by Eustat (Basque Institute of Statistics). All firms are established SMEs, not Start-Ups and are SMEs that are not part of larger firms or family holdings, therefore having a comparable governance structure.

The basic descriptive statistics by size and industrial sector are presented in Table 3, the largest group is basic metals and metal products (42% of the sample), while 18% of the sample are machinery and equipment firms. In terms of firm size measured by the number of employees, 70% of the sample consists of firms with between 20 and 49 employees.

The interviews took place from December 2017 to May 2018 and lasted between approximately 90 and 120 min. Because SMEs often have a single business model (Müller et al., 2018), which is best known by the general manager, in most of the cases the person who was interviewed was the CEO.

The interviews were analyzed using a qualitative content analysis, forming codes from empirical material that was audio-recorded and transcribed (Gioia et al., 2013). To ensure coding validity across several coders, as each interview was coded by two coders, intercoder reliability was calculated following Holsti (1969). A value of above 0.9 between all coders indicates high intercoder reliability.

The interviews were divided into three parts, which are described as follows. The first part focused on introducing both the agency staff and the respondents, and on presenting the objectives of the initiative. The second part started by sharing the inclusive interpretation of Industry 4.0 defined in the project and by asking interviewees about their level of Industry 4.0 implementation and if they had an Industry 4.0 implementation plan. Depending on their answers, agency staff chose the most appropriate survey or questionnaire for the firm (see Table 4). Therefore, the data collection process reflected which stage of Industry 4.0 implementation the firms were in. SMEs are classified according to two dichotomous indicators: Their current involvement in Industry 4.0 and the existence of an Industry 4.0 implementation plan. The involvement in Industry 4.0 is defined as that among the list of advanced Industry 4.0 technologies defined (IoT, Integration of Sensors and Advanced Metrology, Cloud Computing, Data Analytics and Big Data Analysis, Cybersecurity, Modelling and Simulation, and Additive Manufacturing), at least three are already used or in pilot applications. The existence of an Industry 4.0 implementation plan was defined as

**Table 3**
Descriptive statistics of the sample.

| Industry sector | 20–49 | 50–99 | Total | % |
|---|---|---|---|---|
| Basic metals and metal products | 112 | 37 | 149 | 42 |
| Machinery and equipment | 41 | 21 | 62 | 18 |
| Wood and wood processing | 31 | 14 | 45 | 13 |
| Chemistry, Rubber and plastic | 20 | 15 | 35 | 9 |
| Electrical and electronic equipment | 16 | 4 | 20 | 5 |
| Parts for consumer goods industry | 13 | 6 | 19 | 5 |
| Automotive parts | 10 | 4 | 14 | 4 |
| Further or not unequivocal | 5 | 4 | 9 | 3 |
| **Total** | **249** | **105** | **354** | **100%** |

**Table 4**
Data collection process in each category of SMEs.

| Category | Description of the category | Data collection method |
|---|---|---|
| Full implementers (88) | Firms involved in Industry 4.0 implementation including an Industry 4.0 plan. | Qualitative table filled with the information obtained. |
| Non-planner implementers (106) | Firms involved in Industry 4.0 implementation but without a plan that formalizes it. | - Quantitative survey asking for 10 Industry 4.0 conditions, using a 4-point Likert scale.<br>- Qualitative: asking an open-ended question for each condition. |
| Non-implementer planners (4) | This group of firms has an Industry 4.0 plan, although they are not yet involved in its implementation. | - Quantitative survey asking for 10 Industry 4.0 conditions, using a 4-point Likert scale.<br>- Qualitative: asking an open-ended question for each condition. |
| Non-implementers of Industry 4.0 with preconditions (68) | This group of firms fulfills many of the preconditions (they score in the two highest levels of the Likert scale) of Industry 4.0 transition, although they are not yet involved in its implementation. | - Quantitative survey asking for 10 conditions and 9 preconditions for Industry 4.0 using a 4-point Likert scale.<br>- Qualitative: asking an open-ended question for each condition and precondition. |
| Non-implementers with no Industry 4.0 preconditions (88) | These firms are not involved in the implementation of Industry 4.0, nor do they fulfill the preconditions (they score in the two lowest levels of the Likert scale). | - Quantitative survey asking for 9 Industry 4.0 preconditions, using a 4-point Likert scale.<br>- Qualitative: asking an open-ended question for each precondition. |

that there is a formalized plan with milestones for budget, personnel, and processes to implement more Industry 4.0 or existing technologies in significantly more operations. Both indicators were evaluated by territorial development agency that is in close contact with the manufacturing SMEs investigated.

Those SMEs which are not involved in Industry 4.0 and do not have an Industry 4.0 plan are classified according to two subgroups: those which have Industry 4.0 the required resources as a precondition and those which do not. This information was considered crucial for defining the specific policy initiatives for these two groups and to determine whether they were ready to start working on the development of conditions or whether they needed specific programs to develop resources toward preconditions. It is for this reason that the four types corresponding to the two dichotomous indicators were developed into five categories. Table 4 shows the description of each category of SMEs, the criteria for inclusion in each category and its respective data collection method. As described in Table 4, the SMEs that stated they were already involved in the implementation of Industry 4.0 and had an Industry 4.0 plan did not answer any survey or questionnaire as it was assumed that they fulfilled resources for both, preconditions and conditions. For this SME category, only qualitative information was obtained. Table 5 highlights the inclusion criteria for each stage.

**Table 5**
Number of SMEs in each typology (n = 354).

| | | Industry 4.0 plan | |
|---|---|---|---|
| | | Yes | No |
| Industry 4.0 implementation | Yes | 88 SMEs | 106 SMEs |
| | No | 4 SMEs | 156 SMEs |

### 3.5. Quantitative investigation

The preconditions and conditions shown in Table 2 were operationalized in two quantitative questionnaires as shown in Appendixes 1 (preconditions) and 2 (conditions). The exact phrasing and design of the scales was developed in several workshops between researchers, development agencies and policy makers (see Table 1).

For the quantitative survey, 4-point Likert scales were chosen. By not offering a midpoint and providing only few options to choose from, a 4-point Likert scale serves the study's objective to characterize groups that have been defined using qualitative methods (Revilla et al., 2014; Weijters et al., 2010). The absence of a midpoint forces answers to express agreement and disagreement. Although the most used configuration is the 5-point Likert scale as the midpoint option allows respondents to express their uncertainty, the actors involved in the research process argued that it provides them with an "easy" option to choose (Neuman, 2014). Further, a higher number of scale items are not required for this study, as the quantitative approach serves to characterize pre-defined groups rather than serving a more complex statistical model (Revilla et al., 2014; Weijters et al., 2010).

Table 6 presents the measures taken against common method variance, endogeneity, and unobserved heterogeneity in order to ensure causality of the correlations measured.

In order to ensure reliability, validity, and generalizability, Table 7 summarized the respective measures taken.

IBM SPSS statistics software was used to generate correlation matrices for conditions and preconditions. For this, Spearman's correlation coefficients among preconditions and other preconditions, or conditions and other conditions, were calculated depending on the respective SMEs (see Table 4). While 0 indicates no positive correlation, 1 resembles the maximum positive correlation. Correlation coefficients

**Table 6**
Measures against common method variance, endogeneity, and unobserved heterogeneity.

| Potential problem | Measures |
|---|---|
| **Common method variance** may be a concern (Podsakoff et al., 2012), since our survey is composed by single respondents. | As an initial procedure, we pre-tested and discussed the questionnaire with company representatives and country development agency staff to verify the clarity of our survey. To further test the magnitude of CMV, we performed Harman's single factor test in which a single factor loads on all measured items. As the single factors explained less than 30% of the total variance, the presence of CMV is below the threshold of 50% (Podsakoff, 2012). |
| **Endogeneity** could lead to biased results (Bascle, 2008). | We performed Stata's estat endogenous procedure using the Durbin–Wu–Hausman statistics to evaluate the consistency of our estimators. The hypothesis that the explanatory variable is exogenous cannot be rejected for several variable configurations chosen, i.e., all p-values > 0.05 (Bascle, 2008). |
| **Unobserved heterogeneity** leading to errors in correlations (Shugan, 2006). | We assessed the normality of our data by examining the skewness and kurtosis values. The results suggest that our data is normally distributed since all values are between the thresholds of ±2.58 (α = 0.01) (Hair et al., 2018). Further, we verified correlations to be causalities as well as understandability and relevance of constructs by the series of interviews and workshops, as described in section 3.4, which were compared for several industry sectors. Due to the long-term relationship between the country development agencies that know the SMEs investigated in detail, unobserved heterogeneity can further be ruled out (Bascle, 2008). |

**Table 7**
Measures for reliability, validity, and generalizability.

| Requirement | Measures |
|---|---|
| **Reliability** | For qualitative interviews forming the input for the quantitative investigation, intercoder reliability was calculated following Holsti (1969) and found to be sufficiently high. Further, measures and results were discussed with SMEs as well as in a series of workshops between SMEs, policy makers, and country development agency, among other stakeholders. |
| **Validity** | Construct validity was ensured by the measures described in Table 6. In addition, the co-design of measures and discussion of results among several stakeholders and SMEs served to enhance validity further. |
| **Generalizability** | Based on a structural analysis by the European Commission, we claim that the findings are generalizable and transferrable to structurally equivalent leading industrial regions throughout Europe (Navarro et al., 2014). Details can be found in section 3.1. |

below 0.3 are regarded as low effects, above 0.3 as medium effects, and above 0.5 as high effects (Cohen, 1992). Medium and high effects are marked in bold in the results tables (Tables 7, 9, 10 and 12), while insignificant results are not shown, i.e., $p > 0.05$ (bilateral).

## 4. Results

We present the results corresponding to the analysis of the data gathered in the survey-based interviews with SMEs. These results allow each SME category to be characterized according to the classification criteria set in section 3.2. In the following sections, each stage and the characteristics of the corresponding group of SMEs are described, considering their fulfillment of Industry 4.0 resources as preconditions and conditions.

### 4.1. Full implementers (88)

These SMEs mainly belong to medium-high technology industries and are conscious of the advantages derived from Industry 4.0 implementation, considering it a strategic bet. They usually start with an initial assessment of Industry 4.0 implementation, followed by a pilot project which involves integrating one or more 4.0 technologies and a further implementation by including an Industry 4.0 strategic plan. Pressure coming from firms at the higher end of the value chain accelerates these implementation processes, as occurs very often in the automotive sector for instance. Table 8 shows some of the statements made by the county development agency staff who interviewed the SMEs about the features describing this category of firms.

**Table 8**
Statements from the county development agencies staff regarding firms involved in Industry 4.0 implementation and having an Industry 4.0 plan.

| Topic | Quotes |
|---|---|
| Motivation for Industry 4.0 | "*The company is aware of the risk of not adopting digital technologies in its daily activities and of the opportunities they entail for the improvement of both internal and external efficiency for its customers.*" |
| | "*Because they have seen their competitors [in Industry 4.0], they have also begun to carry out these types of actions.*" "*They have been working for 15 years in Industry 4.0, 'pushed' by their customers.*" |
| | "*They collaborate with the cluster associations and technology centers, whenever they need a specialist in any subject.*" |
| Challenges | "*They find it difficult to hire staff with digital skills.*" |
| | "*They created a new profile: the person with technological/ digital competences responsible for the factory.*" |

### 4.2. Non-planner implementers (106)

These SMEs are implementing Industry 4.0, but this process is not formally planned. Firms are conscious of the potentials of Industry 4.0 and hence they are including Industry 4.0 in their current strategic reflection processes, although there is no formal strategy yet. Industry 4.0 technologies are mostly applied in the production phase and the analysis of existing resources conditions for Industry 4.0 reflects an adequate context for its implementation.

The different dimensions are tested for correlations, and they are found to be statistically significant (Table 9). Two main significant patterns of correlations are shown: one concerning market size, competitiveness, servitization, and alliances (external dimension), and the other related to efficiency, strategy, qualified staff, and investments (internal dimension). The first one could be related to the external competitiveness as resources of firms, while the second one seems to be more related to internal resources. Moreover, the matrix shows a strong correlation with market conditions. The implementation of Industry 4.0 depends on the market demand, as the dependence between this and the rest of conditions (except infrastructure) is strong.

Table 10 presents some of the statements made by the county development agency staff describing this category of firms.

### 4.3. Non-implementer planners (4)

This small group of SMEs shows their awareness of Industry 4.0 and their capability to foresee future circumstances. The main reasons for non-implementing an Industry 4.0 transition plan are the lack of demand coming from customers and the unavailability of financial resources for its implementation. Because of the small subsample of only four SMEs, this group was not tested for possible correlations, nor is it qualitatively described further.

### 4.4. Non-implementers with preconditions (73)

This group of SMEs fulfills most of the preconditions for Industry 4.0, and its implementation is seen as a possibility for achieving efficiency gains, although implementation is pending. The group mainly consists of process-oriented SMEs which supply semi-finished components, and they consider that not having an own end-product as well as the characteristics of their sectors (low-technology industries) could limit their resources toward Industry 4.0.

The correlation matrix in Table 11 shows statistically significant correlations among resources mostly associated with the internal dimension of firms (financial resources, alliances, and investments). However, this internal dimension also has correlations with the most external conditions, except for competitors, which seems to be a critical condition. This means that the behavior of competitors influences the fulfillment of conditions in these SMEs.

In comparison with non-planner but implementer SMEs, this group shows a weaker integration level among the different conditions, although on average they exhibit a higher degree of compliance in resources as preconditions, as can be seen in Table 12. Likewise, the matrix illustrates the correlation between the product and innovation, internationalization, strategy, and leadership conditions. This shows the importance of the product when implementing Industry 4.0 and developing further resources.

Several of the statements made by the county development agency staff who interviewed the SMEs, and which refer to the features describing this category are presented here in Table 13.

### 4.5. Non-implementers with no preconditions (88)

About 70% of the SMEs in this group do not have an own end-product and are working in low-technology sectors where Industry 4.0 is not yet present, mainly in the metal industry. In general, these SMEs show a

**Table 9**
Conditions correlation matrix for non-planner implementers (n = 106).

| | | Mean | Std. Dev | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Market | 2.774 | 0.721 | | | | | | | | | | |
| 2 | Competitors | 2.547 | 0.770 | **0.587**** | | | | | | | | | |
| 3 | Servitization | 2.123 | 0.983 | **0.316**** | 0.261** | | | | | | | | |
| 4 | Efficiency | 3.057 | 0.728 | 0.207* | | 0.202* | | | | | | | |
| 5 | Strategy | 3.000 | 0.743 | **0.376**** | 0.214* | **0.310**** | 0.248* | | | | | | |
| 6 | Qualified staff | 2.783 | 0.704 | 0.250** | | | **0.321**** | **0.458**** | | | | | |
| 7 | Finances | 2.981 | 0.756 | 0.261** | | 0.292** | **0.421**** | **0.374**** | 0.287** | | | | |
| 8 | Alliances | 2.594 | 0.848 | **0.415**** | 0.246* | **0.334**** | | 0.285** | **0.310**** | 0.274** | | | |
| 9 | Organization | 2.651 | 0.829 | 0.256** | | 0.205* | 0.201* | | **0.325**** | 0.272** | | | |
| 10 | Infrastructure | 2.906 | 0.981 | | | | | | | 0.242* | | | |

** The correlation is significant at the 0.01 level (bilateral).
* The correlation is significant at the 0.05 level (bilateral).

**Table 10**
Statements from the county development agencies staff regarding firms involved in Industry 4.0 implementation, but with no formal plan.

| Topic | Quotes |
|---|---|
| Strengths | "*Although they have no Industry 4.0 plan, there is total alignment with the firm's strategic vision.*"<br>"*The investments for Industry 4.0 implementation are profitable, although we are still in the process of implementing these technologies.*"<br>"*They have funds available for new investments. They are also interested in public programs.*" |
| Challenges | "*They are not familiar with what servitization means and they feel alienated from it.*"<br>"*They do not know what the exact position of their competitors is concerning this topic and they do not have a formal analysis of this, but rather an informal view.*"<br>"*They do not feel the need for organizational changes because of Industry 4.0 implementation or they are not aware of its implications and potential contribution.*" |

very low level of compliance with resources as Industry 4.0 preconditions. Furthermore, this group is unaware of the advantages that could be derived from Industry 4.0 implementation.

As shown in Table 14, several correlations can be found. The associations seem to be stronger among the dimensions of product, innovation, and internationalization, and also among the dimensions of skills

**Table 13**
Statements by the county development agencies staff regarding non-implementers with preconditions.

| Topic | Quotes |
|---|---|
| Strengths | "*They have a strategic view that combined with a shared leadership and an appropriate management model contributes to efficiency.*"<br>"*Innovation is taking place, from process innovation to organizational and market innovation.*" |
| Challenges | "*Collaboration is usually limited to clients and suppliers.*" *'The experience with collaborators is not very good one and they feel that some of them (such as technological centers) are too far to work together.*"<br>"*It is a traditional and hierarchical firm, although new generations are trying to change the organizational model and foster participation.*" |

**Table 11**
Conditions correlation matrix for non-implementers with preconditions (n = 68).

| | | Mean | Std. Dev. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Market | 2.324 | 0.722 | | | | | | | | | | |
| 2 | Competitors | 2.088 | 0.707 | | | | | | | | | | |
| 3 | Servitization | 1.632 | 0.771 | | **0.373**** | | | | | | | | |
| 4 | Efficiency | 2.309 | 0.966 | **0.308*** | 0.255* | 0.265* | | | | | | | |
| 5 | Strategy | 2.221 | 0.844 | | | | | | | | | | |
| 6 | Qualified staff | 2.088 | 0.942 | | 0.293* | | | **0.468**** | | | | | |
| 7 | Finances | 2.471 | 0.938 | | | | **0.323**** | | 0.299* | | | | |
| 8 | Alliances | 1.941 | 0.751 | | 0.257* | | | 0.241* | **0.421**** | | | | |
| 9 | Organization | 2.044 | 0.836 | | | | **0.328**** | **0.332**** | **0.327**** | | **0.461**** | | |
| 10 | Infrastructure | 3.132 | 0.960 | | | | | | | | | | |

** The correlation is significant at the 0.01 level (bilateral).
* The correlation is significant at the 0.05 level (bilateral).

**Table 12**
Preconditions correlation matrix for non-implementers with preconditions (n = 68).

| | | Mean | Std. Dev. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Products | 2.456 | 1.057 | | | | | | | | | |
| 2 | Innovation | 2.927 | 0.739 | **0.464**** | | | | | | | | |
| 3 | Internationalization | 2.971 | 1.065 | 0.279* | | | | | | | | |
| 4 | Alliances | 2.706 | 0.830 | | 0.275* | | | | | | | |
| 5 | Skills Plan | 2.618 | 0.881 | | | | | | | | | |
| 6 | Skills Management | 2.721 | 0.808 | | 0.246* | | | **0.516**** | | | | |
| 7 | Strategy | 3.044 | 0.700 | **0.300*** | **0.360**** | **0.353**** | | | 0.283* | | | |
| 8 | Leadership | 2.603 | 0.849 | 0.269* | 0.261* | | **0.337**** | | **0.404**** | **0.395**** | | |
| 9 | Finances | 3.206 | 0.659 | | | | | | | | | |

* The correlation is significant at the 0.05 level (bilateral).
** The correlation is significant at the 0.01 level (bilateral).

**Table 14**
Preconditions correlation matrix for non-implementers with no preconditions (n = 88).

| | | Mean | Std. Dev | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Products | 2.159 | 1.123 | | | | | | | | | |
| 2 | Innovation | 2.296 | 0.775 | **0.367**** | | | | | | | | |
| 3 | Internationalization | 2.466 | 0.970 | | **0.389**** | | | | | | | |
| 4 | Alliances | 2.159 | 0.856 | | **0.394**** | 0.218* | | | | | | |
| 5 | Skills Plan | 2.330 | 0.813 | | **0.364**** | **0.322**** | **0.383**** | | | | | |
| 6 | Skills Management | 2.386 | 0.808 | | 0.213* | | | **0.311**** | | | | |
| 7 | Strategy | 2.534 | 0.857 | | **0.431**** | 0.250* | | | **0.366**** | | | |
| 8 | Leadership | 2.171 | 0.820 | | 0.295** | 0.215* | | 0.287** | **0.516**** | | | |
| 9 | Finances | 2.682 | 0.796 | | | | | | | | | |

* The correlation is significant at the 0.05 level (bilateral).
** The correlation is significant at the 0.01 level (bilateral).

management, leadership, financial resources, and strategy. The first one could be related to a product-oriented competitiveness model, while the second one seems to be related to preconditions for non-technological innovations.

The statements for this category of firms can be found in Table 15.

## 5. Discussion

Following the inclusiveness criteria described in the previous sections of the paper, and thus considering the most basic technologies as part of the path toward Industry 4.0, we find that 54% of SMEs are already involved in implementation processes of Industry 4.0. The main condition for this implementation is the competitive pressure coming from value chains and imitation, while strategic planning as a resource toward Industry 4.0 appears to be less relevant. This characteristic seems to be typical of SMEs in the current development stage of Industry 4.0, with many of them being pressured or at least demanded to develop toward Industry 4.0 rather than internally motivated to do so (Horváth & Szabó, 2019; Müller et al., 2018).

Among the further 46% of SMEs which are not yet implementing Industry 4.0, there are two different profiles. On the one hand, 19% of the interviewed SMEs are at a stage where they seem to have the right resources, and thus the potential to integrate Industry 4.0, but are still not taking this step. This behavior resembles the group of SMEs that are capable but reluctant to implement Industry 4.0 (Horváth & Szabó, 2019; Müller et al., 2018). By presenting examples of resources acting as preconditions within this development stage, the paper contributes to the understanding of why SMEs act in such a way toward the implementation of Industry 4.0.

On the other hand, however, the other group that makes up 25% of the interviewed SMEs lacks even the most basic resources that would anchor them into a progressive evolution toward Industry 4.0. To date, this group of enterprises has mainly been neglected in most studies devoted to Industry 4.0, at least in Europe. For instance, many Chinese SMEs face the challenge of transiting from a situation where they do not even have the necessary preconditions to implement Industry 4.0 to a full-scale implementation stage in a short space of time (Müller & Voigt, 2018).

**Table 15**
Statements by county development agencies staff regarding firms that are not involved in Industry 4.0 implementation and do not fulfil the preconditions.

| Topic | Quotes |
|---|---|
| Strengths | "*Internationalization is crucial in the firm. They have made significant efforts in this area and they export 25% of their production.*" |
| | "*The firm has a good financial situation, and they have the capacity for new projects and investments.*" |
| Challenges | "*There is a hierarchical and non-cooperative leadership model; staff do not know what the strategy of the firm is.*" |
| | "*There is no formal training plan; training is offered when needs emerge and there is no provision for it.*" |

Regarding the differences found between the groups in different development stages which were described in the previous sections, we can gain new insights into the role that the various resources play in the transition between stages, as summarized in Fig. 1.

For *non-implementers with no Industry 4.0 preconditions*, the main resources required as preconditions toward Industry 4.0 are aligned innovation management, strategy, and internationalization. While aligned innovation management and strategy relate to internal enablers of Industry 4.0, internationalization especially relates to creating market access that SMEs often lack in contrast to larger organizations (Horváth & Szabó, 2019). This can include the development of own products despite the predominant low-technology status, concomitant with a new strategy toward more complex products which involves internationalization, such as addressing a broader customer base. This category of SMEs is still often limited to workshop and semi-standardized products, which makes Industry 4.0 implementation hard to achieve, even in its initial steps.

The transition from being *non-implementers with preconditions* to *non-planner implementers* is one of the transitions that provide several relevant insights. On the one hand, one of the main differences is the market access or value chain position (i.e., firms further from the end customer). Further, the industry sector, mainly metal industry with semi-finished products in contrast to more complex products, corresponds to one of the main reasons for Industry 4.0 implementation. Further, when comparing these two groups, the first and more obvious difference is the fulfillment of resources required as conditions for Industry 4.0. The empirical differences in the comparative analysis, with the exception of infrastructures, outline the robustness of the analytical framework and the relevance of the resources acting as preconditions and conditions it proposes. The results point to the importance of paying special attention to the resources related to strategical alignment, qualification of employees and efficiency of processes (Mittal et al., 2018). Moreover, the correlation analysis shows that implementer SMEs are characterized by following an integrated management approach to foster the Industry 4.0 transition. This reinforces the argument that Industry 4.0 implementation should be considered from a comprehensive perspective and avoid isolated applications in some specific fields. This relates to the intended horizontal and vertical interconnection, and the therefore required implementation of Industry 4.0 (Kagermann et al., 2013).

In the transition from being *non-implementer planners* to being *full implementers,* the resources acting as main resources are the acceptance of Industry 4.0 in the markets and the availability of financial resources for implementing the Industry 4.0 transition plan. Consequently, SMEs can take a relevant role in Industry 4.0 only when they address a real customer demand, which can either be already present, or responded to actively by reorienting the business model toward Industry 4.0, e.g., adopting a service-based business model (Frank et al., 2019; Müller et al., 2018). Finally, SMEs that are *non-planner implementers* could consider developing Industry 4.0 implementation plans in order to move toward the stage of *full implementers*, as it does seem to reinforce the overall engagement of the firm with Industry 4.0. Moreover, the

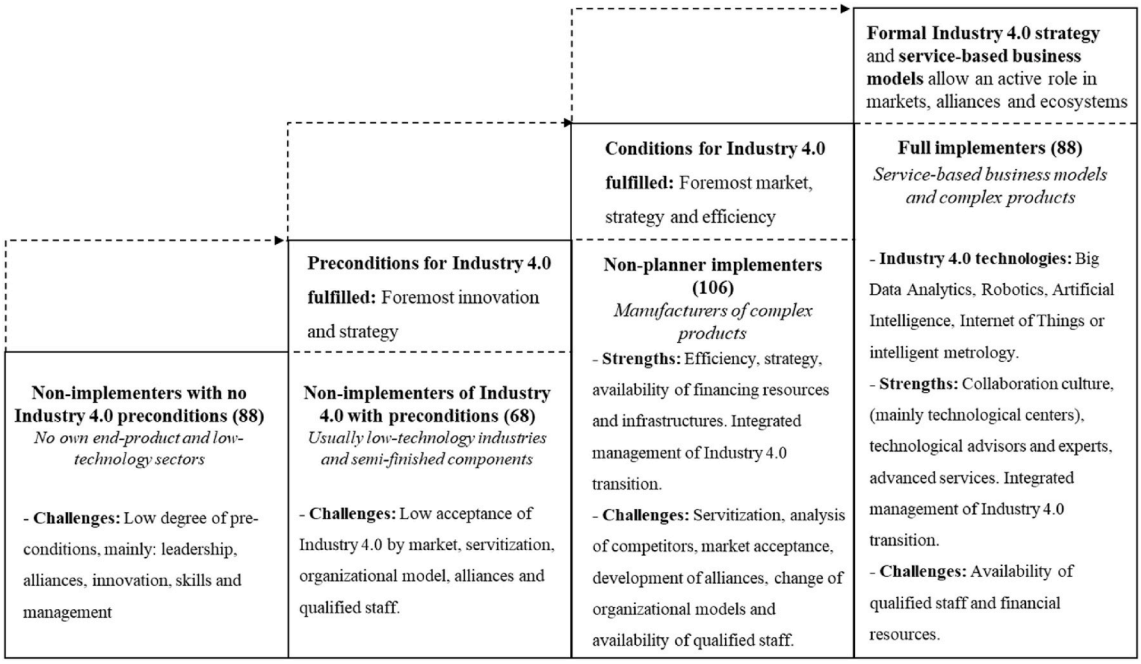


**Fig. 1.** Development stages and resources of SMEs toward Industry 4.0.

adaptation of management models, the analysis of competitors and market acceptance, the collaboration with external actors from the innovation system and the development of new business models through servitization appear to be the main resources acting as conditions of this transition toward full implementation.

In comparison with extant research on maturity models toward Industry 4.0, this research makes several contributions and extensions to the existing literature. The preconditions of having adequate financial resources, skills, and strategy as an entering stage toward Industry 4.0 can generally be found in other studies (Colli et al., 2018; Mittal et al., 2018; Schumacher et al., 2016; Wagire et al., 2020). But whereas most existing maturity models toward Industry 4.0 draw a connection between technologies, strategy, culture and resources (Wagire et al., 2020), this paper extends this view toward the importance of markets, the role in the value chain, extant business models and servitization, as well as alliances and ecosystems. This has not been accomplished so far in conjunction with the aforementioned aspects of technologies, strategy, culture, and resources in its entity (Müller et al., 2018). The availability of adequate products and value offers as a prerequisite for business models can be confirmed in extant literature and is further extended in this paper regarding the dimensions of the market environment and competitors' behavior in different stages (Müller et al., 2018; Schumacher et al., 2016).

Furthermore, our paper introduces several development stages of SMEs and respective resources which are required to reach the next stage, whereas most existing models describe a status quo or only refer to technological assessments (Mittal et al., 2018, 2019). In extant literature, only the stage-gate model created by Müller et al. (2018) develops several stages and enablers toward Industry 4.0. However, this model is limited to the perspective of business model innovation.

In sum, this study is the first to present several development stages of SMEs toward Industry 4.0, incorporating different perspectives of extant literature into a common framework, as described further in the theoretical implications in the next section.

## 6. Conclusion

### 6.1. Theoretical contribution

This study is among the few publications connecting the RBV to Industry 4.0. It is able to gain a better understanding of the relationships between different resources and how resources can be combined to maintain sustainable competitive advantage, in this case development stages toward Industry 4.0, linking back to the original aim of the RBV (Barney, 2001; Peteraf, 1993; Salam, 2019).

Confirming and extending the findings of Bhandari et al. (2020), we find that the combination of resources to achieve sustainable competitive advantage must be accompanied with a respective managerial concept. This concept is represented in our study by the existence of an Industry 4.0 implementation plan. Likewise, SMEs with a higher degree of internationalization are able to engage better in their surrounding markets, networks and ecosystems (Schmidt et al., 2020). In the context of Industry 4.0, we confirm that, to overcome financial constraints, low bargaining power, and market access requires an active strategy as well as an ability to network and acquire knowledge (Müller et al., 2021; Paul, 2020; Ricci et al., 2021). In addition, we confirm that SMEs that have the ability to internationalize their business develop sustainable competitive advantage and are further ahead on the path toward Industry 4.0 (Liñán et al., 2020).

Further, this paper is among the first to research in greater depth the implementation stages of Industry 4.0 and its respective resources required for SMEs. Extant research has mainly focused on maturity models for specific technologies or applications (Dutta et al., 2021; Mittal et al., 2018) or limited to specific cases of companies (Amaral & Peças, 2021). This paper presents the results of a co-design process between policy makers, development agencies, and SMEs which lasted for more than two years. Thereby, it responds to the call for a better inclusion of policy in SMEs' requirements toward Industry 4.0 and a long-term perspective on Industry 4.0 implementation rather than a single point in time (Mittal et al., 2018; Müller et al., 2018). Specifically, the focus here is on the required resources as preconditions and conditions for implementing Industry 4.0. It this way, this paper brings Industry 4.0 research closer to the broad implementation process that starts long before SMEs, which are already on the edge of Industry 4.0,

actually implement it (Eiriz et al., 2018; Verhees et al., 2004). Thus, what is required is a broader implementation process to be able ensure a spanning supply-chain integration of Industry 4.0, which should also include the SMEs that are still far from Industry 4.0 implementation, as well as guaranteeing that preconditions and conditions are established from early on (Frank et al., 2019; Müller et al., 2018; Müller & Voigt, 2018).

In addition, previous research has shown that implementing Industry 4.0 in SMEs is in fact more oriented toward operational benefits than toward strategic advantages (Müller et al., 2018; Sahi et al., 2020). This paper helps to gain a more fine-grained perspective on this operational orientation by showing the development stages toward Industry 4.0. Among others, the sector and market as well as the type of products offered play a decisive role in whether an SME engages in Industry 4.0 and how it approaches it. Therefore, this paper develops an understanding of how research on SMEs in the context of Industry 4.0 should be guided toward the different development stages and specific resources required in each of them.

Moreover, the analytical framework confirms the assumption that SMEs first need to acquire resources as preconditions toward Industry 4.0 in order to develop the necessary resources as conditions that push them forward toward Industry 4.0. In this regard, the paper is able to show that Industry 4.0 still requires several steps in between in order to fully unfold, especially in the case of SMEs (Kagermann et al., 2013; Müller et al., 2018). This paper further presents a more fine-grained view on important resources for SMEs regarding distinct development stages in comparison with extant literature (Ghobakhloo & Iranmanesh, 2021).

From a methodological point of view, the paper shows how academia, public agencies, and SMEs can interact in order to support the implementation of Industry 4.0. The diversity of roles that can be played by researchers in the context of the implementation of Industry 4.0 is understudied, while the role of external observers that gather data and analyze it to explore or predict Industry 4.0 is dominant in extant research. This paper shares an alternative type of process where researchers worked as facilitators of the dialogue process among different policy makers in order to co-construct a methodology for analyzing Industry 4.0. Researchers contributed with knowledge from academia and examples on how Industry 4.0 has been studied in other contexts. Policy makers contributed with their experience in practical design of Industry 4.0 policies and inclusive policy making. Collaboratively, they co-constructed a methodology that not only integrates the state of the art, but also responds to the specificities of SMEs. Therefore, the paper adds to the understanding of the complex implementation process of Industry 4.0 in the intersection of politics, public institutions, industry associations, research, and the actual SMEs involved (Kagermann et al., 2013; Müller et al., 2018).

### 6.2. Managerial implications

This paper can help SMEs gain a better understanding of their positioning, current development stage and resources that act as preconditions or conditions of Industry 4.0 implementation. Hence, SMEs are presented with a comprehensive overview of the development stages toward Industry 4.0 and their respective resources, which allows them to question their current positioning and to actively engage in their behavior toward Industry 4.0 instead of reacting passively. Moreover, by knowing which resources as preconditions and conditions exist for each development stage, SMEs are able to think "one step ahead." For instance, they can actively shape the creation of their necessary preconditions and conditions in advance. Further still, when they reach a particular development stage, they will have a clearer idea of what the respective required resources are so that they can move forward toward Industry 4.0.

With regards to non-planner implementers, we recommend that they formalize the planning and implementation activities toward Industry 4.0, paying special attention to fulfilling the required external and internal resources. Concerning the external dimension, we recommend that market demands and competitors must be considered better, while adopting service-based business models and forming adequate alliances. From an internal perspective, we recommend an appropriate organizational model and qualified staff in order to implement Industry 4.0.

For non-implementers with preconditions, we recommend that the external environment of the SME should be considered in order to find possible applications for Industry 4.0. It may be the case that their existing markets and customer groups have not yet demanded products and services associated to Industry 4.0. However, by developing service-based business models and forming alliances for Industry 4.0-based business models, these SMEs can prepare themselves to engage in new markets, which could in turn lead to new service offerings and Industry 4.0-based business models for their existing customer base in the near future. Likewise, appropriate organizational changes including processes to hire qualified staff or collaboration with externals may prove to be crucial.

For non-implementers with no preconditions, extending innovation and R&D-activities and expanding the range of products is recommended. Through the combination of adequate skills management, leadership and collaboration strategies, these enterprises might then be able to create the required resources as preconditions or conditions for Industry 4.0. Furthermore, rethinking their own positioning toward Industry 4.0 and their extant business model might help them to be better prepared for the future, when Industry 4.0 may become more relevant for them.

From the perspective of politics and public support, there are two lessons that have been learnt from the case which can help SMEs on their path toward Industry 4.0 implementation. The first is the role played by proximity agents (county development agencies in this case), in collaboration with other government levels with competences in industrial policymaking (the Provincial Council in this case). This paper proposes multilevel governance as a mechanism that can help governmental institutions to play a better role (Estensoro & Larrea, 2016) by integrating proximity agents like county development agencies. These do not have formal competences regarding industrial or innovation policies, but are closer to SMEs, allowing them to meet managers face to face and maintain a continued relationship. Thus, multilevel governance can help manufacturing SMEs approach Industry 4.0 positively by generating the context where authorities, governmental agencies and international associations can effectively assist smaller firms with the process of Industry 4.0 implementation (Ghobakhloo, 2018; Müller et al., 2018).

In addition, this paper highlights the connection between social and economic goals addressed through the inclusive nature of the policy process that framed the analysis of SMEs, which is a key feature of the methodology applied. Inclusiveness was interpreted as an effort to adapt policies to the specific needs of firms, depending on their situation. Several European regions and states have set Industry 4.0 as one of their priorities, but the diversification process is not reaching SMEs in every sector, such as the manufacturing industry (Müller et al., 2018). Therefore, this paper highlights the need to integrate SMEs in the implementation process of Industry 4.0 and presents the different implementation stages and respective resources that policy makers, governmental institutions and industry associations can adapt to specific regional requirements.

### 6.3. Limitations and further research

This paper presents a study conducted in one specific territory. Whereas the mixed-method approach that was used in a period over two years served to provide a broader insight into the implementation of Industry 4.0, the respective methods used individually bear several limitations. For instance, the usage of single construct items or constructs mainly derived from interviews and workshops rather than a

theoretical model limits the statistical results of the quantitative approach. However, we claim that as the quantitative approach serves to enrich the qualitative results by presenting additional information on qualitatively defined categories of SMEs, this limitation is bearable.

Further, the regional focus also limits the generalizability. As the integration of policy makers, development agencies and further stakeholders in the process brings many benefits, it also tailors the research approach very closely to the requirements of the specific territory. This does not allow a comparison easily as opposed to choosing established models and testing them in the regional context. However, according to a report for the European Commission, structural similarities with leading industrial regions in Europe allow to transfer the results (Navarro et al., 2014).

In order to further develop the discussion on the implementation stages and its respective resources and to validate the results of this study, the findings should be extended by conducting comparable studies in other regions or in several regions. Further comparisons of influential factors, such as including further industry sectors, firm sizes, or positions within the value chain, could present a fruitful research avenue. Lastly, the recommendations given, and the implementation stages described present the current situation of development toward Industry 4.0. Hence, the effectiveness of the measures proposed and the development over time within the categories of SMEs identified should be supervised closely in future studies. In this regard, it could be of particular interest to observe the behavior of SMEs that are not engaging in Industry 4.0 implementation, i.e., which resources motivate them to participate in the implementation or whether their current business model requires them to engage in Industry 4.0 and to what extent.

In sum, this paper contributes to a better understanding of how different resources serve to develop sustainable competitive advantage for SMEs, differentiated in four different stages of development toward Industry 4.0. Respective preconditions and conditions are derived for each stage, highlighting what resources are required for an SMEs to achieve the next stage. The broad sample of 354 SMEs in Gipuzkoa that is analyzed by qualitative and quantitative means allows to transfer the results to other European regions, considering the high importance and advanced position of industrial SMEs in the Basque Country.

## Note

Participants in the project signed an agreement on the use of data generated in the process that includes the permission of the authors to exploit it for academic publishing.

## Appendix 1. Resources as preconditions questionnaire

| Precondition | Possible answers (4-point Likert scale) |
|---|---|
| Products (access to end customer) | *Strongly agree:* It is directly marketed.<br>*Agree:* We develop our own product but do not market it directly, or we have initiated the development of one/several own products.<br>*Disagree:* We do not have an own product but are interested in having one and we are exploring options.<br>*Strongly disagree:* We do not have an own product, nor do we have any plans to develop one. We will continue to manufacture according to specifications. |
| Innovation | *Strongly agree:* We innovate regularly. During the last two years we have introduced innovation of some kind and have defined an innovation system.<br>*Agree:* During the last two years we have introduced innovation of some kind, but we do have any innovation system.<br>*Disagree:* During the last two years we have not introduced innovation of any kind but would like to improve our conditions to do so.<br>*Strongly disagree:* During the last two years we have not introduced innovation of any kind and we do not have the necessary conditions to do so in the coming years. |
| Internationalization | *Strongly agree:* We export directly. The percentage is higher than 15%.<br>*Agree:* We export indirectly and in a small percentage.<br>*Disagree:* Our company is not an internationalized one, but we would like to improve our conditions to do so.<br>*Strongly disagree:* Our company is not an internationalized one and we expect our market to be regional/national. |
| Alliances | *Strongly agree:* We collaborate continuously according to our strategic plan.<br>*Agree:* We collaborate sporadically without any specific plan.<br>*Disagree:* We have never collaborated but are willing to do so.<br>*Strongly disagree:* We have never collaborated and do not think it is necessary to do so. |
| Skills Plan | *Strongly agree:* We have a training program.<br>*Agree:* We have a training program but have not implemented it or do not follow it.<br>*Disagree:* Our employees develop their competences but we do not have any formal training program.<br>*Strongly disagree:* We do not have any competence development plan and we do not consider it necessary. |
| Skills Management | *Strongly agree:* We have a competence development plan and the staff's views and proposals are taken into account.<br>*Agree:* Despite not having any plan, the development of competences is encouraged and, in general, the staff's views and proposals are taken into account.<br>*Disagree:* We do not have any competence development plan nor any tools to gather staff's views, but we would like to progress in this regard.<br>*Strongly disagree:* The company has a hierarchical structure and staff's competences are not developed. |
| Strategy. | *Strongly agree:* A strategic plan has been developed and drawn up in a document.<br>*Agree:* The plan is not included in any document but it has been developed or those in charge have it in mind.<br>*Disagree:* There is no clear or defined strategy nor do we have a strategic plan, but we are interested and are intending to work on this issue.<br>*Strongly disagree:* There is no clear or defined strategy, and there is no interest or intention to change our way of working. |
| Leadership | *Strongly agree:* A leadership model in which managers take decisions and risks, anticipate problems and encourage the staff to participate.<br>Agreement: The previous characteristics are only partly fulfilled.<br>*Disagree:* The previous characteristics are not fulfilled, but we want to work in that direction.<br>*Strongly disagree:* The previous characteristics are not fulfilled, nor is there any possibility or interest to do so. |
| Finances | *Strongly agree:* We have sufficient financial resources (investment capacity) and do not have any needs in this regard.<br>*Agree:* We do have financial needs but we are taking the necessary steps to address them and have already begun to obtain resources.<br>*Disagree:* We do have financial needs but have not yet taken any steps to address them nor have we obtained any result in this regard.<br>*Strongly disagree:* We do have financial needs but we cannot obtain any funding nor see any possibility of obtaining it. |

## Appendix 2. Resources as conditions questionnaire

| Condition | Possible answers (4-point Likert scale) |
|---|---|
| Market | *Strongly agree:* Industry 4.0 has been implemented in our market sector/field and when analyzing its trend. We see a clear development.<br>*Agree:* Some companies in the market sector/field have started to develop Industry 4.0 ideas.<br>*Disagree:* Only a few companies in the market sector/field have started to develop Industry 4.0<br>*Strongly disagree:* Considering the characteristics of our market sector/field, it is highly improbable that digital technologies or particularly Industry 4.0 technologies will be used. |
| Competitors | *Strongly agree:* All or almost all the main competitors are already implementing Industry 4.0<br>*Agree:* A few competitors are implementing Industry 4.0<br>*Disagree:* Our competitors, in general, are not implementing Industry 4.0<br>*Strongly disagree:* There is no competitor implementing Industry 4.0 |
| Servitization | *Strongly agree:* We are taking (tangible) steps toward servitization.<br>*Agree:* We are planning to move toward servitization and we are defining the steps to be taken.<br>*Disagree:* We are not planning to move toward servitization now or in the near future, and the steps to be taken have not been defined.<br>*Strongly disagree:* We do not see ourselves moving toward servitization in the future nor have we even considered it. |
| Efficiency | *Strongly agree:* Our company is obtaining a return on the investment or has reasons to believe it will in the future (the project feasibility can be determined).<br>*Agree:* We believe we could obtain a return on the investment, but we do not have any proof yet or have certain doubts about it.<br>*Disagree:* We do not believe we will obtain any return on the investment, but we are not certain of it.<br>*Strongly disagree:* We do not believe it can be profitable. |
| Strategy | *Strongly agree:* We have designed a single strategy that includes both.<br>*Agree:* They are not yet fully aligned, but lines of action have already been established which will enable them to converge.<br>*Disagree:* They are not two different strategies, but we do not see any possibility of aligning them or we have not defined this process.<br>*Strongly disagree:* They are two completely independent strategies. |
| Qualified staff | *Strongly agree:* We do not need to hire extra staff, because we can cover our needs with the company's employees. Furthermore, we have started a training program (with specific training needs) and our staff is being trained to develop the skills required by the project or our staff does not need additional training.<br>*Agree:* We need to hire specialized staff and we have already taken the necessary measures. We have already begun to set up a training program to develop our workers' skills.<br>*Disagree:* We need to hire specialized staff or to acquire new skills, but we still have not established any line of action in this regard.<br>*Strongly disagree:* We need to hire specialized staff or to acquire new skills, but we still have not thought of taking any actions in this regard. |
| Investments | *Strongly agree:* We have sufficient financial resources (annual balance) and do not have any needs in this regard.<br>*Agree:* We do have financial needs but we are taking the necessary measures to address them and have already begun to obtain resources.<br>*Disagree:* We do have financial needs but we have not yet taken any measures to address them or we have not obtained any result in this regard.<br>*Strongly disagree:* We do have financial needs, but we cannot obtain any funding nor see any possibility of obtaining it. |
| Alliances | *Strongly agree:* We collaborate continuously according to a strategic plan.<br>*Agree:* We collaborate sporadically without any specific plan.<br>*Disagree:* We have never collaborated but are willing to do so.<br>*Strongly disagree:* We have never collaborated and we do not think it is necessary to do so. |
| Organization | *Strongly agree:* New departments have been created.<br>*Agree:* The duties and activities of certain employees have been changed and the corresponding training actions have already been established.<br>*Disagree:* There have been no changes yet, but certain modifications are being planned.<br>*Strongly disagree:* There have been no changes and no modifications are planned. |
| Infrastructure | *Strongly agree:* We do have a high-speed network.<br>*Agree:* At present we do not have a high-speed network, but it is going to be built.<br>*Disagree:* We do not have a high-speed network but we are assessing whether to build it; or high-speed networks cause problems.<br>*Strongly disagree:* We do not have a high-speed network and we do not expect that this situation will change; or no effort is being made in this regard. |

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