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Strategic Roadmapping Towards Industry 4.0 for Manufacturing SMEs

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Abstract. In recent years, there is a growing focus on the role of small and medium-sized enterprises (SMEs), and their development towards Industry 4.0. One way of supporting SMEs in this effort, is by utilizing the method of strategic roadmapping. This article presents a) a theoretical framework for the use of strategic roadmapping towards industry 4.0, and b) insights from a validation of the framework in four pilots - Norwegian manufacturing companies. The framework offers a systemic view of the company by focusing on five dimensions: business and strategy, product, customers and suppliers, production processes, and factory and infrastructure. Simultaneously, the framework offers a stepwise method to look at these five dimensions from a strategic perspective in a holistic way. The empirical data from the pilot companies offer insights on how the companies take up the strategic roadmapping method into their strategic operations, as well as which topics related to Industry 4.0 get integrated into their future vision, strategies and plans. The results indicate that the use of the strategic roadmapping method supports companies in seeing diverse routes towards Industry 4.0 and provides support in prioritizing relevant projects and activities.

Keywords: Industry 4.0 · Manufacturing SME · Strategic roadmapping.

1 Introduction

The fourth industrial revolution, often referred to by the term Industry 4.0, is connected to the development and growing availability of Information and Communication Technologies, which allow for greater flexibility and customized mass production in manufacturing companies [15]. Many definitions of the term Industry 4.0 have been proposed, both from researchers and industry [3],[5],[14],[17]. For this paper, with the purpose of strategic roadmapping towards industry 4.0 for SMEs, the definition presented by Qin, Liu et al. [14] will be applied. From all the definitions considered, the one from Qin, Liu et al. [14] is one of the more integrative definitions of Industry 4.0, incorporating technological and organisational aspects of companies. Industry 4.0 is then said to include five dimensions: business and strategy, product, production processes, customers and suppliers, and factory and infrastructure.

A small and medium sized enterprise (SME) is in Europe defined as a firm employing fewer than 250 people, with a total turnover that does not exceed 50 million euro [4]. Up to recently, only a small part of the academic research on Industry 4.0 has focused on SMEs, while a larger amount of the research focuses on large enterprises [12]. This is in stark contrast with the number of SMEs actively creating value in industry. Nine out of ten enterprises in the European Union are SMEs, and they generate two out of every three jobs [4]. Several scholars therefore indicate a strong need to study implementation of Industry 4.0 initiatives in SMEs, specifically. Research indicates that, despite the growing number of new tools and technologies, most of them are underexploited, if not ignored by SMEs [11]. Barriers for Industry 4.0 are said to be more evident in such companies [19] and there are indications that a methodical approach for implementation is missing [19], [13], next to a lack of resources. Several scholars [11], [19], [13] highlight a lack of a strategic focus: an operational modus hinders SMEs to go beyond a day-to-day focus, making it hard to think and plan in the long term. This in turn leads to a lack of vision for Industry 4.0 that fits the company.

In conclusion, a clear research gap comes forward from several recent studies, pointing at a lack of strategic perspective and holistic view on industry 4.0 integration in SMEs. With this article, we aim at closing some of this research gap by presenting a theoretical, holistic framework for Industry 4.0 integration in SMEs, in combination with a strategic roadmapping method. Strategic roadmapping as a method offers the opportunity to combine a focus on strategic aspects, with a holistic view on all the different aspects that influence Industry 4.0 integration in SMEs [9]. Next to that, we present insights from practice on the application of the framework and method in four Norwegian manufacturing companies. The work presented in this paper is part of a broader project called *DigiFab*, which focuses on supporting Norwegian SMEs to transition towards Industry 4.0.

2 Framework for Strategic Roadmapping

It is important for companies to understand what is crucial for the successful realisation of a digital transformation, and extensive academic literature on adequate drivers and barriers for Industry 4.0 is currently lacking [19]. However, a limited number of scholars have studied success factors and challenges for the implementation of digital transformation, adoption of IT systems and other relevant aspects of Industry 4.0 in SMEs [19], [20], [21]. These studies point out a number of relevant factors related to organisational issues, aside from technological factors that are crucial in the shift towards Industry 4.0. These include the importance of strategy as a success factor for a digital transformation in SMEs and the value of having a holistic view [15], whereby one can see the connections between the different organisational and technological factors that influence the integration process of Industry 4.0 in SMEs.

2.1 Strategic Roadmapping

A roadmap is a specialised type of strategic plan that outlines activities an organisation can undertake over specified periods to achieve stated goals and outcomes [8]. Roadmapping as a method combines strategic thinking with an integrative view on the organisation and a timeline perspective. Roadmapping has been used in the context of Industry 4.0 for some time, often on an overall level to present a research agenda, upcoming technologies, or trends towards a digital revolution in manufacturing [16], [18], [7]. Some scholars also present roadmapping as a valuable integrative approach for supporting the implementation of, and transition to Industry 4.0 in manufacturing companies [9], [10], [2], [6], [1]. Important elements that come forward in the presented methods are the adaptation to the company's maturity level, customisation to the roadmap based on the organisation's needs, alignment of business areas and processes, and identification and prioritisation of projects. Erol et al., [22], emphasize the need for a systematic integration of generic Industry 4.0 concepts with company specific vision and strategies. The scholars point out a strong interest in methodological support to adopt Industry 4.0 concepts, whereby it is important to bridge a broad vision to the mapping of concrete action points or projects.

Available methods do however not combine an integrative approach and a strategic perspective that goes beyond the operational day-to-day level, with an adaptation to the specific needs of SMEs. Moreover, several of the theoretical models ask for further validation and refinement.

2.2 The Developed Framework for Strategic Roadmapping Towards Industry 4.0

In the *Digifab project*, strategic roadmapping takes a central place, with the overall aim to offer a holistic approach whilst simultaneously making the complexity of Industry 4.0 accessible for manufacturing SMEs. Roadmapping thereby adds a strategic perspective. The theoretical framework takes into account main influencing factors SMEs face when implementing Industry 4.0 [13], [21], [15]. Furthermore, the framework applies a definition with a holistic view on Industry 4.0 that includes five dimensions [14]. These are business and strategy, product, production processes, customers and suppliers, and factory and infrastructure (Figure 1). Each of the dimensions demands changes over time in order for manufacturing companies to be able to reach an Industry 4.0 vision.

The strategic roadmapping for Industry 4.0 framework, illustrated in Figure 2, connects the five dimensions with the main activities of a roadmapping method. It includes a time perspective, starting from the company's status today, and working toward a company vision for Industry 4.0 by defining routes to attain that vision. Combining the five dimensions with a strategic timeline offers the company a systemic overview, visually showing how the different areas are connected, and how they influence each other. Moreover, it makes the company actively reflect on the advantages of working towards integrating Industry 4.0

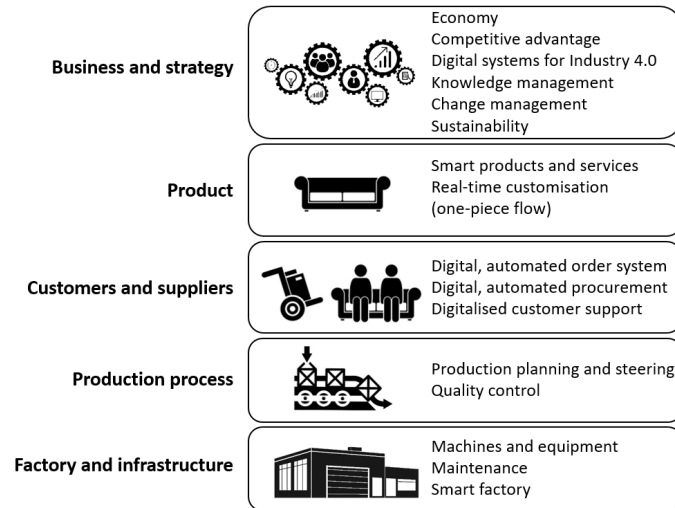


Fig. 1. Five dimensions within Industry 4.0, based on [14]

(Why - vision), what they want to achieve (What - goals) and how to make it happen (How – projects and activities).

Gathering insights on **today's status** is important in order for a company to know where they stand, before deciding where to go. This sounds logical and even almost banal. However, the importance of taking the time to stand still, look at how things are going and reflect on what one has reached – or not – is something that often is marginalised in companies. The insight for today's status is based on input from different sources within the company. It entails information gathered through questionnaires, a company visit and workshops with the management team and employees that focus on the Industry 4.0 maturity level of the company, main challenges and bottlenecks in the company related to the five dimensions, and insights on the company's values and culture.

Company vision builds on the insights from the mapping in today's status. Here the focus is on where the company sees itself in the longer run in relation to Industry 4.0, e.g. in five or 10 years from now. A generic Industry 4.0 vision for the five dimensions (the most right column in Figure 2) serves as a template for a company to develop their own vision. It is important to keep in mind that this generic vision is the optimum maturity level on Industry 4.0 a company can reach, which can guide and inspire a company to develop its own vision and adapt it to its own current state and ambitions. This is important to ensure an organisational fit.

Objectives and activities that will make it possible to reach the vision are combined with a timeline perspective in the five areas. This is first performed in each dimension separately, building further on today's status and vision for that



Fig. 2. Framework for strategic roadmapping towards Industry 4.0

dimension, subsequently breaking it down into objectives for the coming years as well as concrete projects and activities to reach those objectives. Afterwards, all objectives and activities are aligned in order to ensure that they support each other e.g. by looking at dependency, where some activities or objectives need to be reached before another project can be started. It also ensures a good distribution of projects and activities over time so that the roadmap is feasible to implement.

Success factors and obstacles give an overview of possible internal and external factors that can hinder or support a company to integrate Industry 4.0 into its processes and activities. Being conscious about these factors helps a company dealing with possible challenges when they occur.

The framework helps to get an overview of the routes a company can take to get closer to their Industry 4.0 vision on an overarching level. It can be used on different levels of detail, e.g. for detailed roadmaps or action plans in one or more dimensions, within a defined period (e.g. the coming year), or on specific, prioritised projects.

3 Validation and Discussion in Regard to the Pilot Cases

3.1 The Validation Process

During its development, the framework went through iterative cycles of development and testing in four pilot cases. The pilot cases are Norwegian manufacturing SMEs in the following branches: production of 1) metal doors and windows for boat industry, 2) wooden doors and windows for building industry, 3) furniture for offices and shops and 4) products in plastic.

The strategic roadmapping for Industry 4.0 framework has been used a minimum of two times in each pilot case: a) one workshop focusing on developing

an initial Industry 4.0 roadmap in spring 2018 and b) a follow-up workshop in spring 2020 to evaluate the progress and to make adjustments to the roadmap. The two workshops provided insights to the pilot cases as well as to the project team on how the framework is applied and understood in practice. All workshops and interviews were performed with the CEO and management team of each company, supplemented (when possible) with representatives from the production and sales/customer departments. At the end of the second workshop, a semi-structured interview was completed in each pilot, providing insights on the perception on and evaluation of the strategic roadmapping framework.

3.2 Example From Applying the Framework

In this paragraph, we present the final strategic roadmap from one of the cases in the project: The furniture producer Haugstad Møbel AS. Figure 3 gives an example of how they have utilized the framework. This roadmap, created in 2018 and updated in 2019 and 2020, visualizes in a structured and holistic way today's status, the company's vision for Industry 4.0 for 2028 and short to medium long term goals that make reaching this vision realistic. Feedback from the company indicates that the strategic roadmapping was strongly supporting the management at start for raising awareness within the company related to the need for digitalisation and Industry 4.0. On top of that, it helped the company to set concrete goals and to get an overall picture of how decisions influence other processes. The company connected the strategic roadmapping process to other strategic work, whereby the visual roadmap was made available and visible in meeting rooms. Despite that, the active use of the resulting roadmaps was mentioned to come on the background over time.

3.3 Insights From all Pilot Cases

All pilot cases emphasized that the framework gave them a clearer direction: several participants mentioned that it forces the company to think long term and strategically, and that it and supported them in prioritising activities and projects that focus on integrating Industry 4.0. A stronger focus on combining long-term goals with concrete, short-term actions was mentioned as a prerequisite for making the roadmapping method even more applicable for every-day use. The roadmap visualisation was said to give a good holistic overview that makes it more tangible and offers insights quickly in the progress made. Simultaneously, using the method was said to feel chaotic and foreign at the beginning. Participants mentioned they see the value of the framework, but that they need (to allocate) time and supervision to get to know the framework and methodology. Most pilots did not actively use the roadmapping framework between the two workshops; however, insights coming from the workshops have been used in other strategic work. One pilot made up to five versions of their Industry 4.0 roadmap on a regular basis. This pilot mentioned the importance of making a habit of using the methodology at least twice a year as part of strategic processes.

CASE Furniture

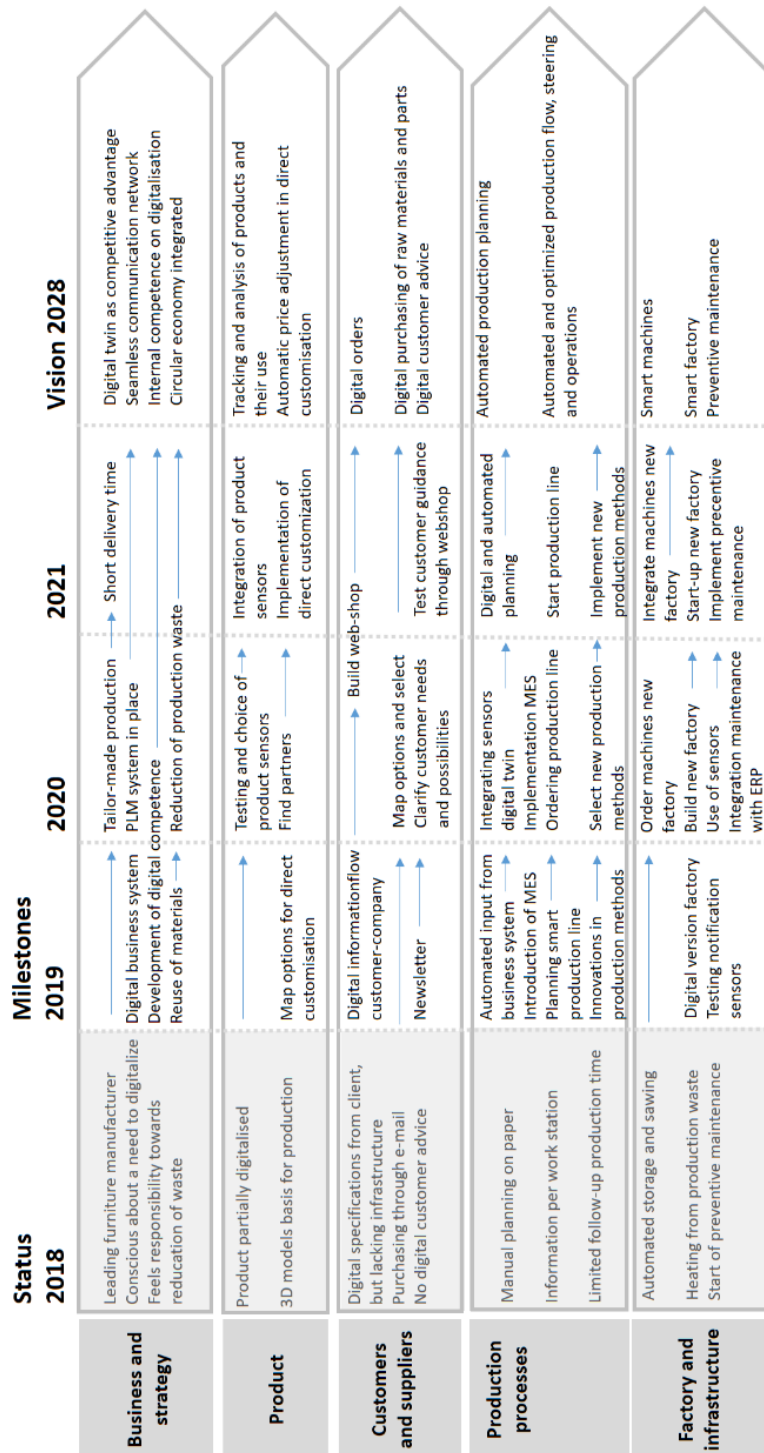


Fig. 3. Strategic roadmap towards Industry 4.0 from Haugstad Møbel AS

Empirical data from the pilot cases – i.e. the different versions of the roadmaps - offer insights on how topics related to Industry 4.0 get integrated into the pilot cases' future vision, strategies and plans. The results indicate that the use of the roadmapping framework supported the companies in seeing more possibilities for moving towards Industry 4.0 from different perspectives, both on the short and long term. On a *business and strategic* level, mass customisation got mentioned in the vision of all four pilots as a competitive advantage that can be strengthened through Industry 4.0. Another common issue from all cases was the large need for defining and choosing a fitting IT system (more specifically ERP system) that fits SMEs and that connects different systems in the organisation in tread with Industry 4.0, incl. customer order systems, production planning, production processes, maintenance, and economics. Working with the framework raised awareness on the need for more knowledge and competences on Industry 4.0 amongst management and employees. This resulted in direct action in some pilots, e.g. through starting a hiring process with focus on the needed digital competences. In general, roadmapping for Industry 4.0 raised focus on *product* development within all pilots, whereby smart products and tracking of products through sensor technology came forward as main topics. Attention for *customers and suppliers* also raised, with topics including the improvement of customer services through automated digital ordering and customisation. Large gaps between the pilots became clear considering the maturity level on *production*: mapping of production planning and processes indicated a stringent need for improved efficiency in two of the pilots before any attention could go to the use of digital technologies that support Industry 4.0. However, three of the pilots envision a smart factory and Industry 4.0 infrastructure in a 3-5 years' timeframe. Other common topics on *factory and infrastructure* includes the vision towards automated maintenance systems.

When looking at the first versus last roadmap version, it shows that the overall vision on Industry 4.0 is stable in the four pilots. However, the last roadmap shows more clarity on how to get there: the early versions of the roadmaps include many projects and activities, which reflects the overwhelming feeling of the participants on starting with Industry 4.0. A better overview, prioritisation and spreading over time comes forward in the latest roadmap. Another change over time could be noticed on how the different dimensions were covered: the early strategic roadmaps turned out to focus mostly on technological aspects of Industry 4.0 - especially related to production processes - thereby putting the systemic perspective on the background. The later roadmaps reflect a more balanced approach to Industry 4.0. The last roadmaps were created during the COVID-19 pandemic. All pilots were affected by COVID-19 to some degree, mostly leading to delays of projects and activities, but no significant changes in the strategic roadmaps. One pilot needed to change its course radically due to a significant drop in orders. They needed to go in 'survival mode', shifting focus towards activities that bring in orders and financial resources and putting other planned projects on hold.

4 Conclusion

In this article we present a framework for strategic roadmapping towards Industry 4.0 for manufacturing SMEs. It aims to address strategic aspects in combination with the need for a systemic view of the company by focusing on five main dimensions. Development and validation of the framework in four pilot cases has offered insights on its application in practice: how it was used and how the users experienced it, main themes that emerged from the pilot cases' roadmaps for Industry 4.0 as well as changes in the roadmaps over time. The validation highlighted that the framework can support SMEs in seeing diverse routes towards Industry 4.0, and that it helps them to work more strategically on integrating Industry 4.0 in different dimensions of the company. As a future development, the use of the framework will be automated, which offers opportunities for further streamlining the data flow, a dynamic use of the roadmapping framework over a longer timeframe, as well as it will provide a digital interface with the companies and users. Further research will focus on how the application of the framework supports SMEs, thereby gathering data from a larger number of SMEs both in Norway and internationally.

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References

1. Anderl, R., Picard, A., Wang, Y., Fleischer, J., Dorsch, S., Klee, B., Bauer, J.: Guideline industrie 4.0 – guiding principles for the implementation of industrie 4.0 in small and medium sized businesses (01 2015)
2. Battistella, C., De Toni, A.F., Pillon, R.: The extended map methodology: Technology roadmapping for smes clusters. *Journal of Engineering and Technology Management* **38**, 1–23 (2015). <https://doi.org/10.1016/j.jengtecman.2015.05.006>
3. Brettel, M., Friederichsen, N., Keller, M., Rosenberg, N.: How virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective. *International Journal of Science, Engineering and Technology* **8**, 37–44 (08 2014)
4. Commission, E.: User guide to the sme definition. Report, European Union (2015). <https://doi.org/10.2873/620234>
5. Erol, S., Jäger, A., Hold, P., Ott, K., Sihm, W.: Tangible industry 4.0: A scenario-based approach to learning for the future of production. *Procedia CIRP* **54**, 13–18 (2016). <https://doi.org/10.1016/j.procir.2016.03.162>, <https://www.sciencedirect.com/science/article/pii/S2212827116301500>, 6th CIRP Conference on Learning Factories
6. Erol, S., Schumacher, A., Sihm, W.: Strategic guidance towards industry 4.0 – a three-stage process model. In: *International Conference on Competitive Manufacturing* (2016)

7. Ghobakhloo, M.: The future of manufacturing industry: a strategic roadmap toward industry 4.0. *Journal of Manufacturing Technology Management* **29**(6), 910–936 (2018). <https://doi.org/10.1108/jmtm-02-2018-0057>
8. IEA: Energy technology roadmaps a guide to development and implementation. Report, OECD/International Energy Agency (2014)
9. Issa, A., Hatiboglu, B., Bildstein, A., Bauernhansl, T.: Industrie 4.0 roadmap: Framework for digital transformation based on the concepts of capability maturity and alignment. vol. 72, pp. 973–978 (01 2018). <https://doi.org/10.1016/j.procir.2018.03.151>
10. Leone, D., Barni, A.: Industry 4.0 on demand: A value driven methodology to implement industry 4.0. In: Lalic, B., Majstorovic, V., Marjanovic, U., von Cieminski, G., Romero, D. (eds.) *Advances in Production Management Systems. The Path to Digital Transformation and Innovation of Production Management Systems*. pp. 99–106. Springer International Publishing, Cham (2020)
11. Moeuf, A., Pellerin, R., Lamouri, S., Tamayo Giraldo, S., Barbaray, R.: The industrial management of smes in the era of industry 4.0. *International Journal of Production Research* **56**, 1–19 (09 2017). <https://doi.org/10.1080/00207543.2017.1372647>
12. Müller, J.M., Buliga, O., Voigt, K.I.: Fortune favors the prepared: How smes approach business model innovations in industry 4.0. *Technological Forecasting and Social Change* **132**, 2–17 (2018). <https://doi.org/10.1016/j.techfore.2017.12.019>, <https://www.sciencedirect.com/science/article/pii/S0040162517312039>
13. Orzes, G., Poklemba, R., Towner, W.T.: Implementing Industry 4.0 in SMEs: A Focus Group Study on Organizational Requirements, book section 9, pp. 251–278. Palgrave MacMillan (2020). <https://doi.org/10.1007/978-3-030-25425-4>
14. Qin, J., Liu, Y., Grosvenor, R.: A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia CIRP* **52**, 173–178 (2016). <https://doi.org/10.1016/j.procir.2016.08.005>
15. Rojko, A.: Industry 4.0 concept: Background and overview. *International Journal of Interactive Mobile Technologies (iJIM)* **11**(5), 77–90 (2017), <https://online-journals.org/index.php/i-jim/article/view/7072>
16. Santosa, C., Mehraia, A., Barrosa, A.C., Araújo, M., Aresc, E.: Towards industry 4.0: an overview of european strategic roadmaps. In: *Manufacturing Engineering Society International Conference 2017, MESIC 2017*. vol. *Procedia Manufacturing*, p. 972–979. Elsevier (2017). <https://doi.org/10.1016/j.promfg.2017.09.093>
17. Schumacher, A., Erol, S., Sihn, W.: A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP* **52**, 161–166 (2016). <https://doi.org/10.1016/j.procir.2016.07.040>, the Sixth International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV2016)
18. Sjøgren, J., Krogh, E., Christensen, L.C., Olsen-Skåre, K.H.: Digitalt veikart - for en heldigitalisert, konkurransedyktig og bærekraftig bae-næring. Report (2017)
19. Stentoft, J., Wickstrøm Jensen, K., Philipsen, K., Haug, A.: Drivers and barriers for industry 4.0 readiness and practice: A sme perspective with empirical evidence. In: *52nd Hawaii International Conference on System Sciences* (2019), <https://hdl.handle.net/10125/59952>
20. Vogelsang, K., Liere-Netheler, K., Packmohr, S., Hoppe, U.: Success factors for fostering a digital transformation in manufacturing companies. *Journal of Enterprise Transformation* **8**, 1–22 (05 2019). <https://doi.org/10.1080/19488289.2019.1578839>
21. Vrchota, J., Volek, T., Novotna, M.: Factors introducing industry 4.0 to smes. *Social Sciences* **8**, 130 (04 2019). <https://doi.org/10.3390/socsci8050130>