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DOI: 10.1016/j.promfg.2020.10.135

Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 51 (2020) 960–966

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2021) 15-18 June 2021, Athens, Greece.

SMEs' Support Functionality Analysis Based on Statistical Analysis

Sara Moghadaszadeh Bazaz*, Sakari Penttilä, Juho Ratava, Mikael Ollikainen, Juha Varis

LUT University, P.O. Box 20, FI-53851 Lappeenranta, Finland

* Corresponding author. Tel.: +358-41-7513311. *E-mail address:* sara.moghadaszadeh.bazaz@lut.fi

Abstract

Industry 4.0 is developing constantly enabling the use of new technologies in various manufacturing applications, including factory floor and production system connectivity and digitally enhanced production processes. The correct use of Industry 4.0 tools improves especially the productivity and transparency of production. However, the use of Industry 4.0 demands knowledge and knowhow. It has been noted that small and medium-sized enterprises (SMEs) lack the knowledge to enable and implement different areas of Industry 4.0. The digitalization level of Finnish SMEs is surveyed in this study, along with a review of the potential support structure for improving the level of implementation of digital processes. A support structure matrix is created to assist the next steps of the SMEs towards Industry 4.0. The support structure matrix created helps SMEs to increase their profitability and competitiveness by introducing Industry 4.0 methods in their operations.

Keywords: Industry 4.0; IoT; support structure matrix; digitalization, SME.

1. Introduction

Utilizing digital technology in manufacturing is a significant requirement from the beginning of the design phase to the end of production and marketing the production then provide maintenance services are compatible. The need of saving resources and providing high quality desired products leads to utilizing computer-aided product development, service-oriented product development to customize products and using service technologies like CAE, CAM/CAD, and ERP to design, control and analysis the production. [2,6]

The digitalization of industry is called Industry 4.0 or the fourth industrial revolution. The original industrial revolution began in mid of 18th century by the invention of the steam engine as a transition from hand production to machining production. The second industrial revolution refers to the period from the end of the 19th century and the beginning of the 20th century with involving electrical inventions, growth of metal production and the introduction of the manufacturing line. The third industrial revolution began with the invention of computers in the 1970s and the growth of digitization in manufacturing, automated machines, and the development of computing in mass production. Today Industry 4.0 interconnects the physical and cyberspace powered by advances in computing, connectivity, machine learning and other data analysis. Even nanotechnology and 3D printing play an important role in Industry 4.0. [1–5]

Digital manufacturing optimizes operational efficiency by improving processes. Its capabilities enhance employee collaboration, connectivity, productivity, and predictive analysis. Furthermore, digital manufacturing increases customer satisfaction by offering customer-specific solutions and cost reduction by enhancing supply chain and enabling “lot size one” production. [6–9]

To improve the level of digitalization on companies, it is important to define the level of digitalization existing in companies. By knowing the level of digitalization, it is possible to detect, mitigate or circumvent the bottlenecks of production. Previous but more general studies about the Swedish industry exist, improving the level of knowledge about digitalization and enabling planning for future strategies both in a company and regional or national level, but to the authors’ knowledge, a

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detailed survey of technologies in use has not been made before. [10–12]

In order to know if there are any bottlenecks in the way to digitalization and what they are it is necessary to know several things. This survey is chiefly divided into two objectives: To find out the current services and technologies in use in the industry and industry-driven needs, and the technologies offered locally. By combining this information, the level of deficiencies in the digital production chain can be spotted: What technologies are in use, what are not in use despite available and what technologies are not available. Geographically, this study is limited to Finland, enabling the authors to send questionnaires in the native language, interview company owners and staff as well as read material published by the companies.

2. Methods

The study has been conducted based on quantitative analysis. In this section, the methods of support structure matrix gathering and the state of the digitalization in companies are presented. Further, the methods of support functionality analysis are presented.

2.1. Support Structure Matrix

The support structure matrix gathered is a database for the services provided regionally within Finland. To gather the available support structure for reaching a higher level in Industry 4.0, a survey was made to gather plenary information regarding service providers and operational digital technologies in manufacturing and mechatronic industries in Finland. This survey was completed based on the Finnish business register and publicly available sources such as company web pages. While not exhaustive, information of 77 operators was gathered. These operators are defined in seven groups as follows.

1. Engineering includes manufacturers or vendors, and manufacturing or mechatronic systems designers. It can be manufacturing companies, educational institute, or company uses design software.
2. IT comprises entities providing supporting software or hardware, including software as a service (SaaS) and cloud models.
3. Competence centers provide expertise for project or program support and typically are skill-based or network-based centers. They can be in contact or integrated with other operations like universities or innovation hubs. There are three subcategories: integration, business intelligence, and industry-led.
4. Educational institutions include universities, universities of applied science, and vocational schools.
5. Digital innovation hubs refer to social communities or research centers that provide expertise on technology trends, knowledge and strategic innovation management, and industry-specific insights. These hubs enable active knowledge transfer between researchers and business experts, on the one hand, and industry, government and representatives of academia, on the other hand.
6. Industrial associations support employees and industry business. It consists of trade union, special interest groups, employer associations, chambers of commerce, SCORE (helps entrepreneurs through mentoring, workshops and educational resources), NFIB (National Federation of Independent Business), and BNI (Business Network International).
7. Public organizations include research organizations and various development organizations such as start-up incubators, Idea Labs, as well as regional and other development centers and fellowships

An operator can be in one or more groups. Although an exhaustive search could not be completed in the time frame available, it was made sure that each group had representation and at least the most important entities were studied.

The support structure matrix indicates the distribution of the digitalization all over Finland. Moreover, it represents the number of actives operators and the level of their offered digital services.

2.2. State of digitalization in companies

The stage of the digitalization in companies in Finland was evaluated by using web questionnaire and company interviews. The goal was to gather the levels of digitalization of manufacturing SMEs' containing ten different categories. 35 companies answered the questionnaire and five companies were interviewed for defining the further problem areas of digitalization and the issues restricting or slowing the pursue to the higher digitalization level.

The questionnaire was done based on the topics of ANSI/ISA-95. The questionnaire had ten main topics and each topic included five questions to gather the level of digitalization in each topic. The topics in the questionnaire were:

1. Digitalization in Customer Relationship Management (CRM)
2. Digitalization in technology planning, product lifecycle management (PLM)
3. Vertical and horizontal value chain integration through Computer networks
4. Digitalization in a Computer-Aided Quality Control (CAQ)
5. Digitalization in production monitoring, using manufacturing execution system (MES)
6. Digitalization in production planning, enterprise resource planning (ERP)
7. Using hardware for digitizing the manufacturing (towards Cyber Physical Systems – CPS)
8. Digitizing the inbound logistics and warehouse management (WMS)
9. Digitizing equipment maintenance process (CMMS)
10. Digitizing quality assurance and laboratory information management (LIMS)

Each question had three options presented: “Not existing”, “Partly used”, “Totally used” giving percentage value of 0%, 50% and 100% points from each answer. Based on the answers in each category, the total level of digitalization is calculated by using average %-points. In addition, company mode of ownership, amount of export business, estimated turnover and estimated number of employees were recorded.

2.3. Support functionality analysis

Comparison of the support structure matrix and the state of the digitalization matrix, it is possible to spot deficiencies and potential solutions. It is also indicative of potentially efficient businesses.

Deficiencies are perhaps the simplest to find out: Are there technologies in the digital toolchain which are not used by companies? Are there services or technology that is not available locally? It is also necessary to evaluate the field, including hardware, software, and labor and training.

Solutions are the second most obvious connection. If some of the services or technologies are not yet in use it can be pointed out how they could be acquired.

The most complex analysis would be showing existing co-operation networks. As the collected data show chiefly company numbers, it is not readily apparent in the data, though high availability of services and technologies combined with a high rate of adoption of the same suggests a well-functioning business.

3. Results and analysis

In this chapter, the results of the support structure matrix and state of digitalization are introduced. Further, support functionality analysis is introduced and explained.

3.1. Support Structure Matrix

The support structure matrix contains a database of active companies in seven groups of operators in Finland. These groups offer technologies and services in ten categories, as mentioned in 2.2.

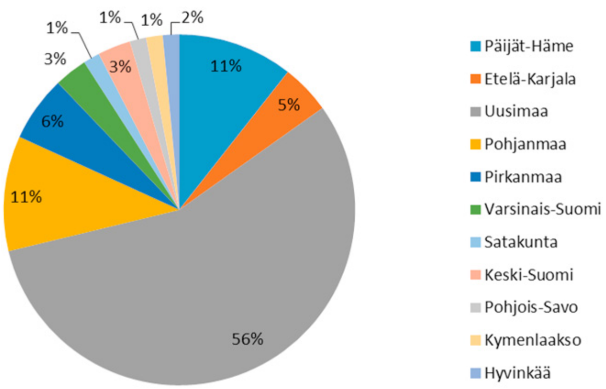

Figure 1. Industry regions in Finland.

Figure 1 shows the distribution of digital technologies in regions in Finland. While this chart is biased in favor of the Uusimaa region due to it containing the capital region and thus many company HQs it is still indicative of the distribution of companies outside of Uusimaa. The second most proportion of digital manufacturing companies belongs to Pohjanmaa and Päijät-Hame with 11%. The other eight regions have less than 10% of the digital manufacturing industry in Finland. Interestingly, the region of Varsinais-Suomi (Finland Proper) seems to be rather underrepresented, considering that the population of Finland is concentrated on a “growth triangle” including Varsinais-Suomi, Uusimaa and Häme.

Figure 2 shows the different fields of operations. The highest number of companies belongs to the operators which offer IT services. The IT services include three types of entities: companies chiefly in the software development business, manufacturers providing both software and machinery, as well as companies providing different Information and Communications Technology (ICT) services.

The educational institutes include six universities, four universities of applied science, and three vocational schools. According to publicly available information, there are 11 competence centers in Finland. Eight digital innovation hubs are active in ICT, Smart, robotics, and EIT digital fields. 10 public organizations and 13 industry associations are considered in the matrix. Some organizations work on multiple fields, though mostly they were counted on their main operating field only. However, if the organization offered IT or engineering services – developing or selling equipment, software or complete systems – it or its relevant division was also counted in this category, slightly boosting numbers but answering the question if technology was available.

Figure 3 depicts the proportion of each service and technology in Finland. 144 entities are having activities related to ERP and 142 entities are having activities related to CPS, the most offered technologies. Based on the field of operations, these entities are located at various points in the supply chain.

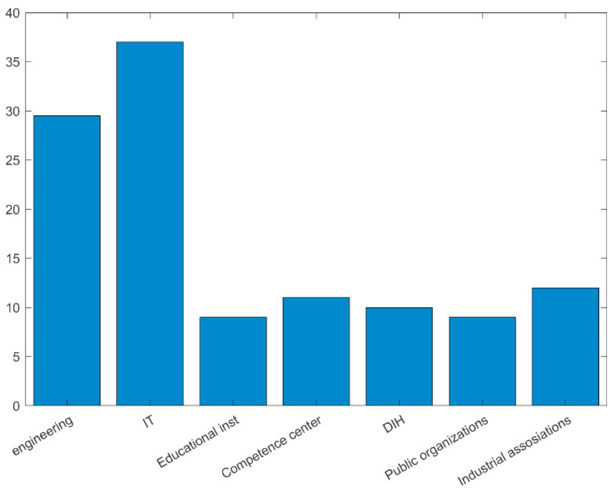

Figure 2: Number of surveyed operators for each field in Finland.

The laboratory information management system category is used and offered by various entities such as educational institutes and manufacturers. The collected data shows that after ERP and CPS, LIMS is the most commonly offered service in Finland.

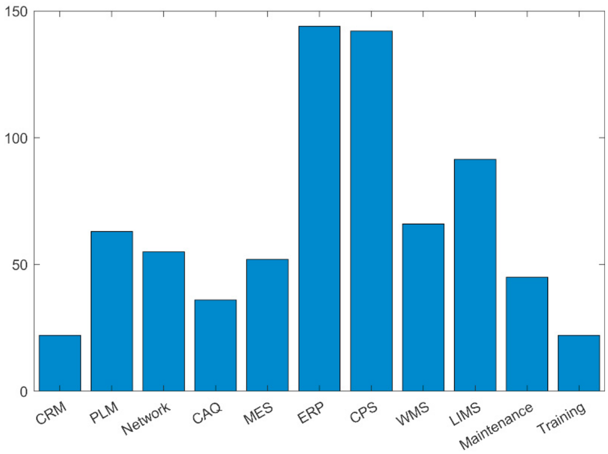

Figure 3: Comparison of the availability of different services and technologies in Finland.

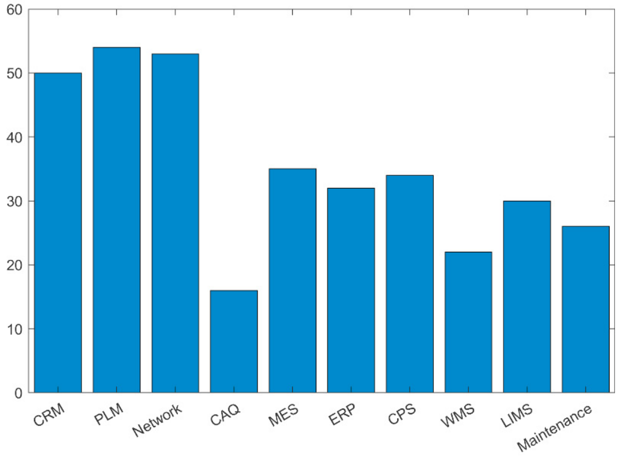

Figure 4: Average stage of digitalization in SME companies in Finland.

Among the whole available services and technologies which are studying in this survey, PLM, WMS, and MES involve in almost half of the sampling data. Networks service which implicates IT services have the ranking near to the average of the most IT services like PLM, MES, WMS, CAQ, and CRM. Of the technological categories, maintenance and CAQ have less than third the popularity of ERP and CMS. The least offered services are CRM and training. Training includes educational institutes as well as companies expressly offering training for the use of their products.

3.2. State of digitalization in companies

The results of the state of digitalization in the company questionnaire show the average level of digitalization in each category. Figure 4 shows the percentage level of technologies utilized within each category. Based on the percentage level, the CRM, PLM, and Networks are the three most used technologies, each having 50-54%. While standalone CRM and PLM solutions do not appear to be very popular offerings, interviews in the companies reveal that these features are present in commonly-used ERP systems, though companies wished for more training to use the features properly.

All companies had a wide area network (WAN) access and most of them used LAN or WLAN in their business, resulting in a good level in the Networks technologies. The lowest level of digitalization (16% on average) was found in CAQ technologies. A major explaining factor seems to be company size and batch sizes. Those companies which had more standardized production and larger batch size tend to use automated CAQ systems. However, companies that had mainly small batch sizes or single production did not use automated systems. Based on the interviews, the companies found these systems too complicated to use if the batch sizes were small. Also, the companies that used CAQ systems found that the accuracy of systems is consistent, reliable, and relatively easy to use. However, there have been issues in understanding the measurements of the system from the customer side. In the system used in the interviewed company measurements are compared to drawings. The system used does not separate necessary and unnecessary dimensions in the finished product and therefore, it could show out of tolerance errors for practically irrelevant dimensions. One possible solution is additional training services to improve the interpretation of measurement results.

The MES, ERP and CPS technologies shared a similar digitalization level from 32-35%. The use of MES systems was found to be dependent on the use of ERP systems – companies who used ERP were significantly more likely to use MES for real-time production monitoring and setting the goals for the production. Smaller companies that did not use ERP did not use MES related technologies. Based on the interviews it was noted that companies with less than 15 employers found that digital production handling was irrelevant and "just made things more complicated". The use of CPS technologies was divided based on batch sizes. With higher batch sizes the companies tend to use more automation, whereas in a single production or small batch sizes the use of the systems was minimal. Based on the interviews with the companies it was noted that the setup times and return-of-invest times were too high for the low production numbers.

Nearly all companies used an ERP solution, and the low score in this category is explained by difficulties in the use of its features. Interviews confirmed a characteristic large amount of manual transfer of data between systems and a lack of knowledge to use the existing digitalized solutions.

Digitalization level in the WMS, CMMS and LIMS technologies ranged from 22-30%. A warehouse management system that was integrated into the ERP was commonly used in companies. Also, RFID and barcode type product recognition were commonly used. The material handling in storage was almost completely manual, with only a few companies using automated or partly automated systems. The same procedure goes with CMMS. Maintenance and spare parts were handled well in the system, but the reordering process was manual or semi-automatic. Considering LIMS technologies, almost all companies were gathering some data about the production but its use in optimizing production was rare. Interviews suggest that companies do not require additional training in WMS, LIMS or maintenance technologies.

3.3. *Support functionality analysis*

In the matrix, digital technologies are defined with their subsets. Analyzing the data demonstrates the more useable subsets in the manufacturing industry. Figure 5 illustrates the share of each component in technologies and services in detail. ERP and CPS with 22-21% are the highest provided technologies. ERP facilities such as scheduling, planning, data management, project management and supply chain management are almost at the same, high level, and thus further adoption of these features is most likely reliant on the availability of training. General word-of-mouth seems to provide subjective confirmation for the demand for training to use these systems, which should provide a low hanging fruit for improving the level of digitalization. This might be necessary even in national-level policy or education to drive further profitability.

Different Internet of Things (IoT) solutions for networking devices are the most available of the CPS technologies. Various kinds of general equipment are the next most commonly available and followed by industrial automation and machine intelligence solutions. However, there are few companies working on industrial robotics.

Warehouse Management System (WMS) allocated 10% in this study. These results come from the communication technologies, mobile computers and industry database which are provided by several (different) manufacturing companies. Digital product data contains product lifecycle management, product information management, product data management and the other parts that have a 9% share in industry digitalization in this study. However, it is expected that these features are both available and in use, though part of an ERP system. In this area, there is no drive from the software or systems side. However, the digitalization could be improved by training and up to date knowledge in companies. The level of knowledge in companies could be improved by arranging training sessions provided in cooperation with service or system providers and innovations hub or universities.

Manufacturing execution system (MES) and vertical and horizontal value chain integration through computer networks have quite similar proportions (8%). Collecting data, general equipment and process scheduling in MES allocated the most share of this group. Again, there is an overlap among the adoption of these services in MES and services in CPS and ERP. Simultaneously, the same happened in computer-aided quality control and quality control in LIMS.

MES, CPS and LIMS categories had a good number of providers, and the companies that were needing the services had the services needed. The smaller companies did not need any of the systems, but the knowledge where to find the service if needed was existing. Therefore, it appears that knowledge of the technologies has been shared appropriately.

The CAQ category was not widely used in the SMEs. CAQ for adaptivity and automated measurements were used, however, in the traditional hard automation used by companies having large batch sizes. This is not common for Finnish SMEs. There are service providers in Finland, but some parts of the services are missing. Therefore, if the companies would need such services, they would need to contact suppliers abroad.

Networks, CPS, PLM and CRM categories were well used in the companies, and there were service providers in each category as well as support and training sectors. Therefore, there is no need for actions related to improving the digitalization in these sectors.

It can be stated that the companies were aware of the technologies that could be implemented in their production. However, there was a lack of knowledge about the benefits of implementing Industry 4.0 related technologies. Also, there was a lack of knowledge in the tools already in use (mainly ERP systems). With improving the knowledge about the Industry 4.0 technologies and training of the data management tools, the systematic data management could be achieved. Thus,

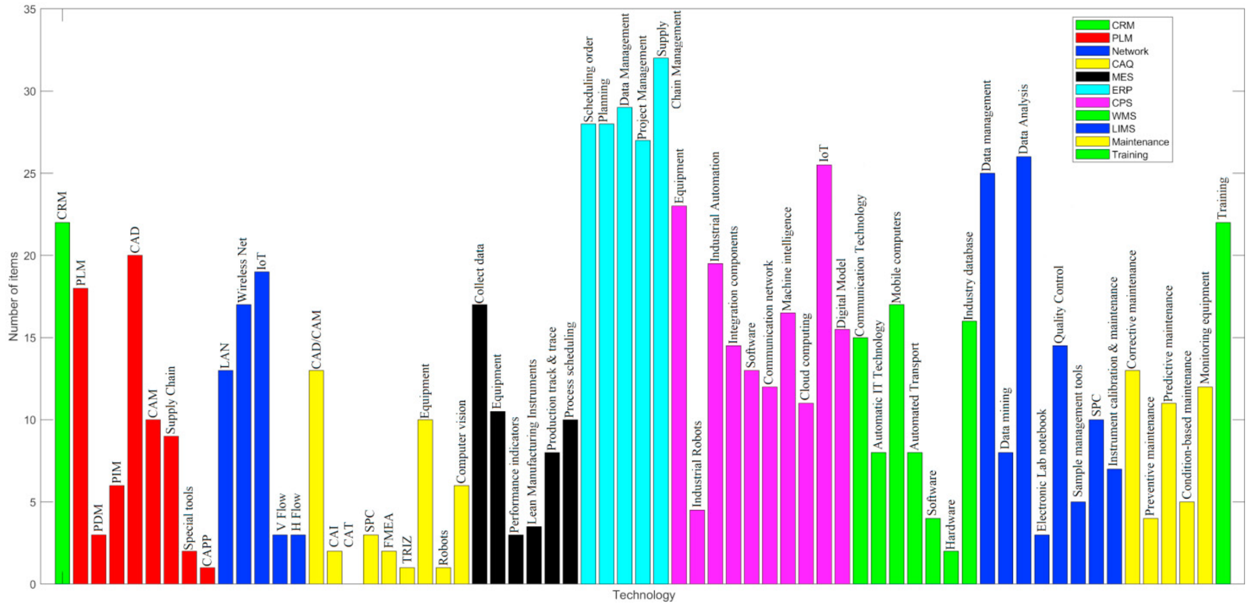

Figure 5: Share of each component in technologies and services.

increasing the profitability of the production industry in Finland.

4. Discussion

The goals of the gathering data in support structure matrix are investigating the level of digitalization in manufacturing metal products, mechatronics, and analyzing the type of offered services in Finland. The collected data covered various entities from policymaking and lobbying, education, and providers of new technologies and supporting services. The responsibilities of these entities are in studying new knowledge, offering new technologies, and supporting the services. The analysis outcomes show what kinds of digital technologies are in use and available.

The support structure matrix provides a database of 77 operators in Finland that offer required digital service and technology in the industry. The functionality analysis is the bridge between the survey had been done on 30 small and medium-sized companies and the support structure matrix application. The functionality analysis assists the manager to make the connection with experts to solve their problems or improve production lines, saving resources, marketing, or connection with customers. They could choose the experts from the closest educational institutes, competence centers, or digital innovation hubs to develop research regarding the effects of using new technology in their organization. The small companies need to figure out an efficient way to move from traditional business management or any manual process to use modern digital facilities. For instance, as mentioned before, there are some issues in using ERP entirely. The combination evaluating on support structure matrix and functionality analysis gives a useful vision of the software companies which present ERP software and provide training sessions for their customers. Furthermore, these results demonstrate how strong or weak is Finland in particular technology from the sight of science and equipment.

The reliability of the state of digitalization is dependent on the amount of data gathered. The higher the number of companies for the digital gathered gives a better response in the actual situation at the national level. While the sample size is not statistically significant in the traditional sense of the word, it does represent a large portion within the scope of this study and thus can be considered reliable.

Considering the validity of the study, each category of the topics of ANSI/ISA-95 was analyzed and evaluated according to an experimental plan. The study brought up a few categories where the companies are lacking Industry 4.0 technologies. The most surprising result was that many of the tools within the ERP systems were not used even the companies were using the ERP itself. With a modest amount of training, the companies could get more out of the services they already pay for, potentially increasing the level of digitalization of their processes and reducing manual data input and paperwork, which most certainly would affect profitability.

Compared to earlier studies, this study provides a deeper analysis of the adoption of the technologies in the form of the support structure matrix, state of digitalization in companies and support functionality matrix. The internal classification of different technologies is built using the ANSI/ISA-95 as a formal framework for foundational technologies for Industry 4.0. The closest studies [10–12] do not provide similar detail. To be able to evaluate the bottlenecks in utilizing Industry 4.0, it is crucial to know the state of digitalization in companies to apply relevant action. Not only practical actions can be done to mitigate bottlenecks, but larger-scale decisions are apparent to improve the state of digitalization in the manufacturing and mechatronics industry.

The Finnish government has a digitalization strategy for SME's operations. Significant financial support is available. For SMEs, up to 50% of the investment and development costs could be supported to improve their operations and competitiveness. With the information provided by this study, the critical areas of the improvement in terms of utilizing Industry 4.0 can be pinpointed and a roadmap can be created. The roadmap could be used as a tool to evaluate different strategical impacts to reach Industry 4.0 in both government and regional levels to maximize the effectiveness of actions.

The very recent increased funding for the enterprises and the need for increased amounts of communication technology in response to social distancing measures to combat the COVID-19 does also provide further motivation towards Industry 4.0. The effects for the industry are disrupted at least momentarily, but some changes might be permanent and not all changes have yet unfolded. The need and utilization of digital innovations at all points of the supply chain are near certain to increase.

The level of digitalization would be beneficial to be analyzed in other countries so that the state of digitalization can be evaluated on an international level. International support functionality analysis would also provide connections at the international level and could improve the cooperation between the countries and improve the overall efficiency.

5. Conclusions

In this study, the digitalization level of Finnish SME's was evaluated by questionnaires and interviews based on the ANSI/ISA-95. Also, the support structure matrix supporting the companies in the same ANSI/ISA-95 categories was evaluated. According to the support structure matrix, there is a satisfying level of digitalization in subsets of cyber-physical systems and enterprise resource planning. In the case of the CPS, universities support the teaching, developing, and implementing the installation and application of CPS in industrial companies, However, the cost of using automated CPS systems such as robots, machine automation, or communication network would not be cost-efficient for small enterprises. The survey shows, although the great available ERP service in Finland, there is a lack of experts and knowledge to use different applicable services in ERP to replace hand working by a digital system.

In terms of computer-aided quality control, small and medium-sized companies prefer to do the quality control manually due to complexity and low batch size. However, CAD is a preferable service to utilize for many companies, it is suggested to develop other sub-systems of computer-aided quality control. Particularly, computer-aided inspection and computer-aided testing need more investigation to offer them in the market. The regularity in subsets of each service or technology shows that despite the digital technology is available in Finland, but it requires more progress in different subsets.

The study shows that the level of digitalization in companies could be improved by using a support functionality matrix as a tool to investigate the potential areas of improvements in the way to Industry 4.0. Knowledge level of tools and methods to improve the digitalization levels in SME's could be improved by training and education. Thus, it could be possible to improve profitability and simplify data management with such actions.

Acknowledgements

This work has received funding from Interreg Baltic Sea Region project Innovation Framework for Challenge Oriented Intelligent Manufacturing (INforM), grant number #R078.

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