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

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SM Bazaz[1], S Penttilä[2], M Ollikainen[3], J Ratava[4], J Varis[5]

[1] Research Assistant, LUT University, Lappeenranta, Finland
[2] Junior Researcher, LUT University, Lappeenranta, Finland
[3] Project Researcher, LUT University, Lappeenranta, Finland
[4] Associate Professor, LUT University, Lappeenranta, Finland
[5] Professor, LUT University, Lappeenranta, Finland

Email: Sara.Moghadaszadeh.Bazaz@lut.fi

Abstract. The aim of the research is to provide a sample data and analysis to present the state of digitalization in the Baltic sea region. A matrix contains seven operation fields and ten services and technologies mapped available digital services in six countries like Denmark, Estonia, Finland, Latvia, Lithuania, and Poland. A comparison analysis describes the level of digitalization strength and weakness areas by country in Baltic sea region. Support structure analysis is a reference to select the suitable partner to enhance the level of digitalization in countries. The results show that there are differences in the strength and weakness areas in Baltic sea region. Further the strength areas of each country are compared to weakness areas of digitalization to develop a roadmap to improve the readiness to implement and use Industry 4.0 functionality and tools.

1. Introduction

Manufacturing industry is rapidly digitalizing. Integrating manufacturing with modern communication technologies, automation, and robotized boost availability, flexibility, reliability and maintainability in manufacturing industry. [1,2] In addition to various production technologies utilized as a part of a production chain, the complete computer-aided process of delivering affordable high-quality products requires several digitalized systems. [3,4] Digitalization assists companies in measuring performance, efficiency to arrange a plan to reach goals of the company. [5,6] Key benefits of digital manufacturing are improved employee collaboration, connectivity, productivity, and potentially autonomous process analysis and improvement capabilities, known as Industry 4.0. [7,8] These together allow enhancing the supply chain to the point of enabling customized lots of a single product. However, onboarding new technologies in the dominantly SME manufacturing industry can be challenging. [9,10]

In this study, a dataset collected by questionnaire is combined with manufacturing companies' capabilities collected by interviews or listed on public sources such as web pages.[1] From this data, it is possible to see the existing level of digitalization in each of the studied countries, and in the case of potential improvement, see if the relevant technologies are available in the country. For specialized maintenance, it is also important that the services are provided nearby.

[1] This work has been done as a part of the Interreg Baltic Sea Region project Innovation Framework for Challenge Oriented Intelligent Manufacturing (INforM), grant number #R078.

2. Methods

The digitalization structure and readiness for the Industry 4.0 in metalwork manufacturing is evaluated with six countries in Baltic region: Denmark, Finland, Estonia, Latvia, Lithuania and Poland. First, method to gather the state of digitalization in companies -questionnaire and the support structure matrix survey in each country is introduced. Further the method to analyse the differences in the digital readiness and need for support structures in different categories between countries is explained.

2.1. State of digitalization in companies in each country

The state of digitalization in each country in the survey by web questionnaire and company interviews. The level of digitalization in companies' questionnaire was based on the ANSI/ISA-95 classification of systems. Thus, ten main topics was derived in the questionnaire including five questions each topic. The questionnaire consisted following topics:

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 (CAQC);
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 Systems (WMS);
9. Digitizing equipment maintenance process via Computerized Maintenance Management System (CMMS);
10. Digitizing quality assurance and Laboratory Information Management System (LIMS).

The questionnaire questions consisted of three answer options: “Not existing”, “Partly used”, “Totally used” giving percentage value of 0%, 50% and 100%. The total cumulative results of each topic were calculated by using average % of the total answers separately for each country. While this scale is coarse, with a sufficient amount of answers, a quantitative analysis can be performed.

2.2. State of digitalization support in each country

The level of the support structure of the companies in the study was gathered in the form of survey. The survey consisted information of service providers and operational digital technologies in manufacturing industries gathered with publicly available sources. The operators in the survey were divided in seven groups as follows:

1. Engineering includes manufacturers or vendors, and manufacturing or mechatronic systems designers;
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;
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;
6. Industrial associations support employees and industry business.
7. Public organizations include research organizations and various development organizations.

The support structure matrix indicates the distribution of the digitalization in each country, presenting the number of digital services available in each category. Each operator in the survey can fit in multiple groups depending on the operator’s area of expertise.

2.3. Comparison of level of digitalization of companies in the Baltic sea region

The level of digitalization in each country in the study were compared between the categories provided in 2.1. The data of each country was plotted in the bar chart divided in the groups presented in 2.1. The data set consists of 64 entities in Denmark, 27 in Estonia, 85 in Finland, 62 in Latvia, 60 in Lithuania, and 71 in Poland. The collected data may be used means to explore and find the suitable solution for

needed services. Some overlap and related specialization are apparent. For example, an IT company provides ERP, MES, and PLM services suggests a developer or vendor of a management software suite. An engineering and IT company providing PLM, CPS, LIMS, and maintenance suggests a manufacturer of CPS with services to support its main product such as PLM for product development, LIMS to test its product and provide maintenance for its customers. And there are educational institutes and research hubs which are active in several fields and their role in supporting the industry. The differences in the readiness for Industry 4.0 was presented and the lack of required digitalization level in each category between the companies was evaluated.

2.4. Support functionality analysis of the Baltic region

Support functionality analysis of each country in the study was evaluated by plotting the data of each group presented in 2.1 in the form of bar chart. The differences in the support structures between the countries were evaluated. The support structure matrix and level of digitalization in companies in each country were compared to find the improvement areas of digitalization. Further the improvement areas were compared to countries support structure matrix to find the support to category from other countries in the study. Finally, the roadmap to increase the level of digitalization and readiness for Industry 4.0 implementation in Baltic region is presented.

3. Results and Analysis

The collected data set, while not exhaustive, may be considered representative of the level of activities in each country, see Figure 1. It is readily apparent that, relatively speaking, Denmark, Estonia, and Poland have an engineering-heavy sample. Estonia and Denmark have relatively fewer IT companies, whereas the data set includes many Polish companies having activities on that field with the other countries having a good number of companies in the sample. Estonian part of the data set has a high representation of educational institutes, competence centres, and digital innovation hubs; many of these are public organizations suggesting a high level of communal support. For the supporting entities, Poland and Denmark had relatively few educational institutes listed in the sample; Finland, Poland and Denmark had few competence centres. No digital innovation hubs were listed in the study for Poland and few for Denmark. Estonia had an especially high share of public organizations, with Finland and Denmark having few. Latvia and Estonia listed a higher number of industrial associations, whereas Denmark had none in the sample.

The structure of the entities studied varies between countries. There is relatively little overlap in all countries. In Finland and Denmark, education institutes are listed to provide engineering and IT services In Estonia, Latvia, Lithuania, and Poland education institutes are listed to provide engineering, IT services, competence centers, and digital innovation hubs. The individual services or technologies supported are shown in Figure 2 which illustrates the distribution of services and technologies among in the six countries studied. Note that this illustrates the share of entities studied that offer services or products of this type relevant to their operating fields. We may roughly divide the services to more commonly used (PLM, VH, CAQ, MES, CPS) and less used (CRM, ERP, LIMS, maintenance).

Finland, Estonia, and Poland have a relatively high degree of services offered in Product Lifecycle Management. In vertical and horizontal value chain integration, Estonia has the highest share over 50%. with Poland and Denmark having the lowest level of adoption. In Computer-Aided Quality Control, Poland seems to be the only notable outlier, having relatively low level of availability. For manufacturing executions systems, Denmark has a high level of services offered, with other countries having a lower level and Finland coming in last. In Cyber-Physical Systems, Denmark appears to take the lead (study was conducted in the “Danish Robot Valley” in Fyn) with other countries enjoying a good level of adoption.

In Customer Relationship Management, Estonia and Finland have the highest level of support, with relatively little interest in Denmark. One might assume that such functions may be included in ERP systems, which appear to enjoy good support in Estonia and Finland, some support in Lithuania but surprisingly low support otherwise. For Warehouse Management Systems, all partners have a similar rate of adoption; some functionality may be included in ERPs. Denmark seems to have a lower rate of WMS services or products offered. In Laboratory Information Management, Finland and Estonia seem to have a higher level of digitalization than the other partners. Finally, maintenance systems appear to enjoy better level of support in Finland than elsewhere.

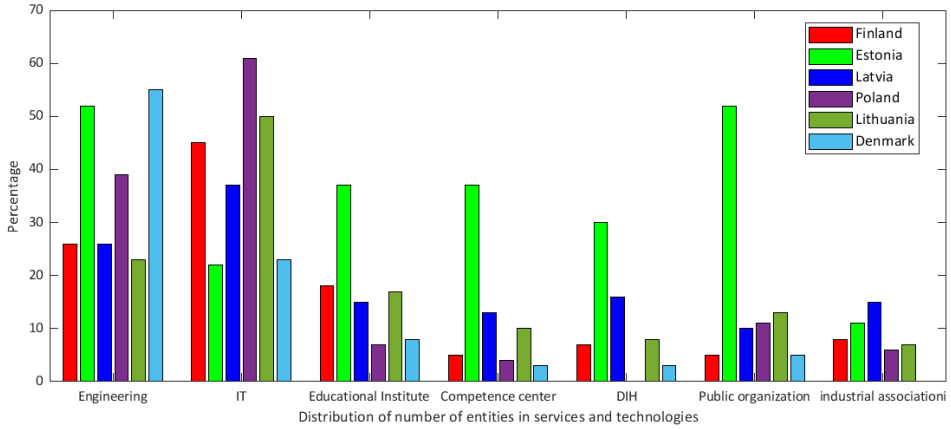

Fig 1. Distribution of manufacturing-relevant entities in each country. One entity having divisions in different fields means totals may add up over 100%.

Overall, Estonia and Finland seem to have a high level of readiness for Industry 4.0, with a comparative focus on customer and customer satisfaction-oriented systems, services and technologies such as ERP, CRM and LIMS. The Danish part of the study suggests significant competence in manufacturing automation. Lithuania appears to be having a slightly higher level at many of the less-adopted systems compared to its neighbors.

As a rough estimate, under 15% share of companies providing a service in a country might warrant a concern for availability, and under 30% indicate some room for improvement. These are apparent in the collected data. Overall, we may conclude that the availability of maintenance systems important for keeping high-tech equipment running smoothly is low. Outside of Estonia and Finland, ERP, CRM, PLM, and LIMS seem to need improvement. Denmark has a low share in most technologies outside of CPS, MES and CAQ, though it might be that the number of robotics companies is relatively high in the sample. Other notable opportunities for improvement include VH and CAQ systems for Poland and CAQ systems for Latvia.

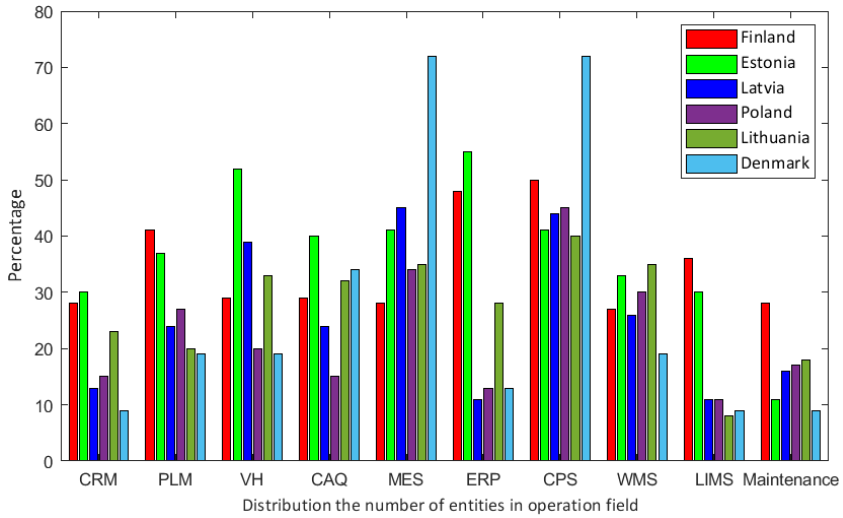

Fig 2. Country comparison - services and technologies supported (percent of entities listed)

4. Discussion

The reliability of the study is dependent on the data gathered. The data does not represent the whole view of the companies nor service providers and therefore the results of the study does not give absolute

result of the digitalization level of the companies in each country. However, the experts in manufacturing have been doing the surveys and questionnaires in each country and therefore the study presents a brief but easily generalized overview of the level of digitalization and support structure in Baltic region.

The results of the study can be applied in the practice by acknowledging and sharing the information between the countries via e.g. digital platform offering easy access to companies for the information. Companies can find the suppliers, vendors and knowledge about the Industry 4.0 benefits as well as practical steps how to apply the theory in practice. Thus, the level of digitalization can be increased in the companies. By increasing the level of digitalization in companies the Industry 4.0 can be implemented further in practice. This can not only enhance the viability in the company level but also in national as well as EU level. However, the language barrier between the countries might affect the applicability as especially SME's in Latvia, Lithuania and Poland are not using English as a commonly used language in everyday work life. Hence requiring the translation process in between the service providers to increase the effectiveness. For further study, a wider database of levels of digitalization in whole EU could be applied to increase the collaboration and potentially competitiveness of EU.

5. Conclusions

The survey about the digitalization level of six countries in Baltic region has been done based on the surveys and questionnaires. A resulting support structure matrix consists of seven operation fields and ten services and technologies. Information has been collected of the popular and available entities in its industrial region. The full results may help the countries to develop policy and find out their weakness and strengths in ten important and useful digital technology area. The support functionality analysis assists countries and entities in the countries to collaborate with the other partners to enhance their digital level in industry. Overall, Finland and Estonia have good availability in most services. Danish robotics cluster is notable. Denmark, Poland, and Latvia need to improve some services and Lithuania has the average share among the countries. Along with maintenance automation, CRM, ERP, and LIMS have the most potential to be improved to reach higher level of digitalization.

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