Network-based automation for SMEs

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Abstract: The implementation of appropriate automation concepts which increase productivity in small- and medium-sized enterprises (SMEs) requires a lot of effort, due to their limited resources. Therefore, it is strongly recommended for small firms to open up for the external sources of knowledge, which could be obtained through network interaction. Based on two extreme cases of SMEs representing low-tech industry and an in-depth analysis of their manufacturing facilities this paper presents how collaboration between firms embedded in a regional ecosystem could result in implementation of new automation solutions. The empirical data collection involved application of a combination of comparative case study method with action research elements. This article provides an outlook over the challenges in implementing technological improvements and the way how it could be resolved in collaboration with other members of the same regional ecosystem. The findings highlight two main automation related areas where manufacturing SMEs could leverage on external sources on knowledge – these are assistance in defining automation problem as well as appropriate solution and provider selection. Consequently, this paper develops and discusses a set of guidelines for systematic productivity improvement within an innovative collaboration in regards to automation processes in SMEs.

Keywords: innovative collaboration; small- and medium-sized enterprises; SMEs; automation; open innovation ecosystem.

Reference to this paper should be made as follows: Parizi, M.S. and Radziwon, A. (2017) 'Network-based automation for SMEs', *Int. J. Business and Globalisation*, Vol. 18, No. 1, pp.58–72.

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1 Introduction

Fostering innovative and entrepreneurial behaviour becomes increasingly important in busting global economic development (Wong et al., 2005; Dana, 2001; Nordqvist and Melin, 2010; Porter and Stern, 2001). The steady growth of the global market demands the pursuit of new approaches to product development and innovation. Competitive behaviour and time pressure require undertaking actions that help companies in adapting to rapidly changing business environment. Hodge and Ratten (2015) suggest a resolution to this issue in the form of organisational improvisation, which could not only have a positive impact on organisational performance, but also stimulate organisations' internal learning. Nevertheless, in order to improvise, firms must have a certain level of expertise and appropriate competences, which is not always the case of small- and medium-sized enterprises (SMEs). Scholars tend to discuss the lack or shortage of resources in small firms (Dahlander and Gann, 2010; Spithoven et al., 2013). This applies not only to financial means, but also to human resources, since internal resources are not something that SMEs can fully rely on. In order to grow and expand, they have to exhibit more cooperative behaviour, both in the local and international markets (Fink et al., 2008).

In this paper, we assume that in order to achieve the overall economic growth, a local contribution is required, preferably through creating new workplaces, establishing new ventures, and maintaining innovative companies. That is why present research focuses on a regional collaboration project, where different stakeholders tried to support regional competitiveness through knowledge sharing (Farinha et al., 2014; Fernandes and Ferreira, 2013).

The high cost of the manufacturing process, as well as the labour in industrialised countries, makes it more difficult for manufacturers to compete with the developing ones. At the moment, outsourcing strategies are among the most popular remedies to this problem (Cui et al., 2012). Although these strategies may reduce the production costs in the short run, they can be followed by many long-run challenges, e.g. long distance transportation resulting in high-cost supply chain and extension in lead times. On the community side, some economic issues, such as rising unemployment, can arise as adverse effects to the outsourcing strategies. This may also have a very negative effect on the regional development. Therefore, we see a need for new collaborative strategies targeting lower costs in manufacturing and added product value, where product customisation and reduction of lead time are in focus. These strategies are of special interest in the context of manufacturing SMEs. Through applying collaborative strategies to product development and the improvement of manufacturing processes through knowledge sharing, small enterprises could not only improve their businesses, but also have a positive impact on the regional ecosystem.

The main objective of this study is to propose solutions to development challenges experienced by SMEs embedded in a regional innovation ecosystem. Thus, this study attempts to explore how collaborative efforts and a purposive knowledge-sharing environment could stimulate SME's production facilities' improvement. The research question that we address is: how can one develop a set of generic guidelines for regional ecosystem members, which could help them in automation problem solving? Here, we focus on two extreme case studies of manufacturing SMEs, which took part in two regional automation projects. The region of Southern Denmark consists of a few large market players and a relatively large number of small manufacturing firms, which express very different attitudes towards knowledge exchange and collaboration. Our study is based on a wide empirical base of interviews, reports, meeting minutes and observations conducted from 2013 to 2015.

Our intended contribution in this article is firstly, to provide an outlook of the challenges in implementing technological improvements, and secondly, to present how innovative collaboration could inspire the development and implementation of the right automation solutions.

The article is structured as follows: We begin by introducing the key theoretical concepts of collaboration in an open innovation environment and the contemporary automation issues. Next, we proceed to the methodology section, where we discuss the subject of the study and the way in which the empirical data were collected. Then, we present the main findings and open the discussion. Last, but not least, we conclude with both limitations and further research recommendations.

2 Collaboration in open innovation environment

The literature describes different ways in which various business networks, clusters and entrepreneurial ecosystems could contribute to regional development through innovation (Asheim et al., 2006; Baptista, 2000; Maskell and Lorenzen, 2004), knowledge generation, and diffusion (Audretsch and Feldman, 1996; Baptista and Swann, 1998; Malmberg and Maskell, 2002; Saxenian, 1994). However, this concerns mostly firms located in a special local ecosystem (Spencer et al., 2010). Moreover, there are new challenges in today's business environment related to globalisation, and the rapid development of information and communication technologies, thus there is a high degree of knowledge diffusion across multiple public and private organisations, which discourages enterprises from innovating on their own (Van de Vrande et al., 2006).

Hagedoorn (1995) underlines the increasing importance of forming strategic alliances. Technology has become so complex, and technical knowledge so scattered, that even for large enterprises it is difficult to handle innovation alone (Bougrain and Haudeville, 2002; Fusfeld, 1986). Therefore, companies try to acquire extensively dispersed knowledge through network interactions (Bougrain and Haudeville, 2002). The key to stimulating cooperation is spatial proximity (Powell et al., 1996; McKelvey et al., 2003; Davenport, 2005; Audretsch, 1998). Public authorities have been trying to foster technology transfer and inspire regional initiatives by creating proper environment for successful knowledge sharing (Rosenfeld, 1996).

The new paradigm of open innovation (Chesbrough, 2003) has been slowly replacing the traditional model (Moore, 1996). It helps companies to adapt to changes in the business environment through acquisition of new ideas from external knowledge sourcing (Chesbrough, 2003). Open innovation takes place both in large enterprises and in smaller organisations. Due to many technological challenges, it could have a much larger influence on the latter, due to their relatively small financial resources for research activities. SMEs, typically from the low-tech sector, engage in collaboration activities with other firms of a similar size more often than with high-tech firms which operate in global markets (Kleinknecht and Reijnen, 1992). This gives them a chance to accumulate both capabilities and resources.

Companies that interact through networks have access to more sources of external knowledge, which could improve their operational activities (Foss et al., 2013; West and Bogers, 2014; Brunswicker and Vanhaverbeke, 2015). Ratten et al. (2007) also list a set of other drivers for European SME's internationalisation besides membership in networks or clusters these are: internal resources and capabilities; favourable government policies; economy, competitive market conditions, and industry structure. Innovation and 'international entrepreneurship' (McDougall and Oviatt, 2000) do not happen in vacuum, but rather within a domain of activities that include domestic and international business environments (Ratten et al., 2007). Therefore, in order to understand the innovative and entrepreneurial decision-making process, theoretical perspectives that examine both the national and international institutional environments are needed (Zahra et al., 2005).

Studies on innovation in SMEs show that the main motives for pursuing cooperation in innovation are market-related reasons such as meeting customer demands, or keeping up with competitors (Van de Vrande et al., 2009). In comparison to large firms, SMEs encounter more challenges in attracting highly-skilled specialists (Rothwell and Dodgson, 1994), as well as in accumulating financial resources (Van de Vrande et al., 2009). Moreover, small firms usually develop their capabilities with a certain focus on core competitive areas; in many cases this pushes them to outsource other non-core activities. Expanding their networks of potential partners could help SMEs to find missing capabilities and acquire more innovative resources. SMEs that open up their boundaries have a chance to become important players in the modern innovation landscape (Van de Vrande et al., 2009). That is why our research has examined technology exploration in the form of production process improvement through a collaborative automation project.

Successful collaboration in an innovative project is related to the alliance structure (Suseno and Ratten, 2007) and processes that promote cooperation and the transference of knowledge (Child and McGrath, 2001). Such collaborations are based on shared job-related interests. Therefore, intrinsic incentives to share knowledge are required (Swift and Hwang, 2013). The knowledge sharing between firms is based on mutual respect, shared values, perceived competency (Reagans and McEvily, 2003) as well as a level of mutual trust between partners (Das and Teng, 1998). The latter has received widespread attention in the literature on buyer-seller relationships, relationship marketing, strategic alliances, business-to-business relationships, and investigations of importer-exporter relationships (Bianchi and Saleh, 2010; Suseno and Ratten, 2007; Morgan and Hunt, 1994; Voss et al., 2006; Brenic and Zabkar, 2004).

Companies that understand customers' changing expectations and respond to them quickly and with appropriate products have a substantial advantage over competitors (Stalk and Hout, 1990). The changing business environment and market demands have led manufacturers to apply new approaches in production, which initiate the emergence and development of new production paradigms over the years. New manufacturing concepts and technologies have begun to be implemented more and more extensively in the manufacturing industry. Product variety increases due to factors such as: changes in energy price and trade structures, internationalisation of the market and the growing sophistication of customers (Clark and Fujimoto, 1991). Consequently, the variety in production has steadily increased and the volume per model has dropped.

SMEs in general exhibit more flexibility in manufacturing in comparison to larger firms; therefore they have the advantage of providing customised products, which make them more competitive with a low production volume of a wide variety of different products required. The request for greater responsiveness to changes in products, production technology, and markets have led to the emergence of the concept of flexible manufacturing systems (FMSs) in the field of management and production (ElMaraghy, 2005). That is why flexible manufacturing strategy is considered to be a workable production strategy that could enable SMEs to increase their productivity levels while keeping the desired level of customisation.

3 Automation in SMEs

Automation enables manufacturing units to attain accuracy and speed advantages that a human could not achieve (Taylor et al., 2013). Manufacturing units significantly benefit from automation because it drives production costs down and increases productivity by reducing manufacturing time, improving quality, reducing waste, and enhancing energy use. The automation solutions can be applied to objects, which include: machines, tools, devices, installations and systems on the areas of software, hardware or mechanical. In the manufacturing line, automation solutions are more focused on manufacturing groups, which are: assembly, process handling, material handling, test and quality control, transportation, information flow and logistics planning. Lean philosophy focuses on achieving excellence through the principles of continuous improvement and waste reduction. It brings some advantages to companies, such as higher quality production, lower inventory levels, improved productivity, and shortened customer response times (Fullerton and McWatters, 2001). Lean principles have been pointed out as an element of a strategic importance for the production systems. The aim of this strategy is to obtain competitive production based on: the right combination of manufacturing principles; motivated and qualified employees; the level of automation; and cooperation with suppliers and customers worldwide. Therefore, the automation solution in a manufacturing plant can be applied for specific factory requirements, to reduce waste. Lean automation has been defined as “a technique which applies the right amount of automation to a given task. It stresses robust, reliable components and minimises overly complicated solutions” [Jackson et al., (2011), p.3]. Within the lean approach, automation aims to assure that equipment or processes function in a way that helps to detect and remove all undesired states that could possibly lead to manufacturing defective products (Shah and Ward, 2003). Both manual and automated processes are used in effective lean production systems; but the challenge is to determine the appropriate type of automation (Shah and Ward, 2003). Lean production engineered according to characteristics of a manufacturing plant should answer two questions. First, what should actually be automated? Second, what, in the process, does not have to be automated? According to

Rother (2001), manufacturing processes that can be considered for automation are classified in four groups including: load machine, machine cycle, unload machine and transfer part. Regarding to the maturity of the automation level in a manufacturing plant, the priority of automation in each group will be determined. To suggest an automation solution to a manufacturing unit, especially in the case of the SME, it is essential to think about the production system. Full automation of production processes and the use of machinery may not necessarily be the best choice, but in some cases, it undoubtedly is. Using machines with more functionality can cause a decrease in utilisation of labour. However, SMEs should consider keeping a high-level of flexibility and holding down the costs. If a company builds its production system around a multifunctional machine, they take equipment and components with high-levels of operational time, and combine them into a machine that does not provide that level of uptime and short changeover (Harris and Harris, 2008). To achieve a flexible, efficient, world-class production system, there is a need to recognise the impact of the various forms of automation solutions and machine design on a lean production system. After deciding on the best solution for a production system, an automation solution can be chosen to improve flow and fit into the flow. "Lean is not manual, but the right type of automation is required" (Harris and Harris, 2008).

4 Research methodology

This manuscript presents findings from an inductive inquiry, which explored possible implementation of automation solutions in SMEs. During the period between 2013 and 2015, the researchers undertook two action research projects: AutoSyd and SAFIR. These projects covered the geographical area of Southern Denmark, where 147 manufacturing SMEs were contacted and 78 accepted a free automation consultancy from the project. As a part of these projects, companies were offered analysis of their current automation set up, as well as free consultancy regarding strategic planning and the implementation of improvements. The researchers together with industrial automation partners applied an action research approach, which helped to establish relationships with visited firms and develop an in-depth understanding of their automation challenges. Action research methodology is perceived as a process in which academic and practical knowledge is integrated with existing organisational knowledge and combined to solve emerging problems (Shani and Pasmore, 1985). Through this distinctive collaborative process between scholars and practitioners, organisational insiders and outsiders, researchers aimed to provide meaningful support for SMEs, as well as to create actionable knowledge that is useful to practitioners, and robust for scholars (Coghlan, 2011; Coghlan and Shani, 2008; Shani and Pasmore, 1985).

The collection of a solid empirical base of interviews, reports, meeting minutes and observations led us to choose a comparative case study method (Yin, 2009) focusing on the company level as a unit of analysis. The selected manufacturing SMEs represent similar sections of low-tech industry. Their different levels of knowledge and understanding of automation and manufacturing philosophies have caused them to be at different levels of using automation solutions and improvement opportunities within the manufacturing line. Therefore, their selection supports the purpose of this study.

The empirical data collection was conducted in cooperation with two regional automation projects: the AutoSyd and the SAFIR project. Both were established to support SMEs in Southern Denmark with investigating, evaluating, and implementing new automation solutions into their manufacturing facilities. The AutoSyd project facilitated collaboration between project participants in order to get a structured analysis of manufacturing facilities, as well as recommendations in regards to practical strategies and plans for company-specific automation. Furthermore, the AutoSyd Project helped participants by developing activities, such as targeted courses providing updated knowledge and expertise in automation. The SAFIR project provided an interactive and collaborative technological network of manufacturing companies, automation providers and independent experts who supported automation choices and problem solving processes in SMEs. Through the SAFIR project, manufacturing companies were supported in specifying and documenting possible automation projects as well as evaluating them based on financial, technical and strategic concerns in order to create a company specific automation road-map. By utilising a morphological technology database, SAFIR either both searches and communicates with a group of automation providers within the scope of existing solutions, or matches require competencies with potential solution providers. Furthermore, the SAFIR project assists manufacturing companies in selecting the most competitive partner and facilitates collaboration between project participants in order to ensure that they get a head start with specific project implementation activities.

5 Data collection

Semi-structured interviews were conducted with members of the AutoSyd and SAFIR projects, as well as with industrial experts who have experience working with a large number of SMEs. The interviews precept an appropriate perspective on SMEs' challenges and helped in evaluating their needs in regard to the manufacturing processes with a special focus on automation. It was aimed to investigate how SMEs realise and approach their needs for improvements on the manufacturing line, and to understand how they invest on new solutions to develop new manufacturing business ideas. In order to find answers to our research questions, we have chosen a sample of two extreme cases among typical companies representing low-tech industry and made an in-depth analysis of their manufacturing facilities. The emphasis of the study is on automation solutions, which SMEs have used or developed in order to improve their manufacturing lines. Our cases, which for confidentiality reasons will be further called Company A and Company B, are represented by Danish manufacturing SMEs that had considered automation within their manufacturing facilities. The researchers gathered the data through observation of the manufacturing lines, face-to-face unstructured interviews with company representatives, and secondary data about the company. Between interviews, companies were asked to fill out an online survey touching upon their products, customers and manufacturing competences. All the data gathering methods together with multiple investigators involved in the process helped us with data triangulation (Eisenhardt, 1989).

6 Sample description

Company A has started as a family business and was transformed into a privately-owned. It employs 200 people, and its main products are: bathroom furniture, covering closets, mirrors, drawers, sinks, accessories, etc. Its main markets are EU countries (primarily Scandinavia) and Russia. Orders are 75% standardised, and the company competes directly with other brands. Core components of their products are purchased from exclusive sub suppliers. This renders a strong customer-supplier dependency. The workers at Company A do not have any specific skill background. They mostly have been at the company for many years, which equips them with a high-level of tacit knowledge. Assembly constitutes the main element of the manufacturing process. Due to short delivery time and long supplier lead-times, the company needs to hold a large stock in order to be able to cope with fluctuation in both demand and design. Some areas of improvement have been recognised in a series of manual processes, handling and eliminating the Kanban inventory. There is also potential of re-organising the two assembly working cells related to the 'specific furniture'. At the moment, these two small assembly cells located with working stations, are 'connected' through a Kanban inventory. Initially, the company doubted the ideas of the suggested changes, especially because they were not taking things like space and cost savings of the ideas into account. Thus, a more thorough analysis was needed. As a result of further discussions and idea generation meetings, a survey of the potential improvement areas of Company A was conducted. The outcome of this survey was summarised in the final presentation of a solution with a conveyor belt between the various workstations, which was created in SketchUp Make and presented, along with prices and expected savings. Company A seemed positive about the outcome, and decided to take the ideas in their deliberations, but indicated that probably it will not be implemented 1:1.

Company B is also a privately owned company with 25 employees. About 75% of them work in the production line. The main business area of Company B is supplying steel, alloys and titanium products to business customers within agriculture, food, and offshore (oil and gas) industries. Company B has only few customers with repetitive orders. Due to a failure in an earlier automation project, the owner hesitates to make new automation investments. All manufacturing involved employees are considered as skilled workers. Much of their knowledge is tacit, as there is a very low-level of standardisation. The main part of the manufacturing line is semi-automatic, and the main product is produced on cutting machine tools. There is also a series of manual processes, for handling special operations, deburring processes, measurement and control activities. The design of the factory layout is functional and orders are passed from one operation to the other.

In the first step, three possible automation projects were identified:

1. to automate loading and unloading items from the saw, clean chips and prevent them from spreading across the production line
2. to automate measurement of fabricated items immediately after cutting processes
3. to automate deburring processes of machined items.

Initially, the CEO and the production manager had different opinions about the importance of each of these projects. However, automation experts helped them get a better understanding of recommended improvements and the expected benefits of their implementation. Afterwards, priorities were set and an automation road-map has been created. The automation project members helped Company B in finding a number of automation providers specialised in the field of the selected project, which focused on automation of the deburring processes. As an outcome, Company B received three different innovative proposals from the potential providers, and after a consultation with automation experts they have chosen the most 'consistent' and relevant innovative solution. The selected solution consisted of a semi-automated solution where 80% of deburring processes will be done automatically and just 20% of the work will remain manual. This will result in a relatively large amount of savings and additional profit to the company, estimated with about one year of a payback period.

7 Findings

SMEs, regardless of their current level of automation are facing different types of challenges. Investment decisions in automation are a long, complex and costly process, preventing a successful result for many SMEs. There is a real lack of technology-based tools to support manufacturing companies in identifying and evaluating their automation projects and in facilitating collaboration with automation providers in a smart and efficient way.

In this research, the business owners of Company B were aware of problems and possibilities for improvement in the manufacturing line, but they were not able to identify and evaluate them s properly. The managers of Company A have had the experience of utilising automation solutions in some parts of their manufacturing, and they knew the specific problem clearly, but they had some issues in finding appropriate solution.

The solutions offered by large companies or global automation providers do not necessarily meet SMEs requirements properly. It mostly happens because large companies are not fully aware of the manufacturing needs of SMEs. Moreover, some of the existing solutions include 'unnecessary features', which often make the product way too expensive.

On the other hand, SMEs that are aware of their manufacturing needs thus potential improvements, are struggling with other issues, namely designing and implementing solutions, which will comply with their needs. Some of these limitations come from the lack of financial resources and expert labours (Van de Vrande et al., 2009). These constrain their capabilities of conducting regular R&D activities as well as hold them back from pursuing new investment that do not fall into the scope of their core competencies.

One approach to solve automation challenges in SMEs is collaboration and knowledge sourcing from outside of the organisation. This could help SMEs to clarify their improvement opportunities and benefit from external capacity in order to strengthen or increase their internal technical capabilities. In regards to our research this issue was reflected and solved through external collaboration and assistance offered to Company B. Industrial automation providers and automation experts helped them in gaining a better understanding of the problems and prioritise these in the most efficient way. The lean wastes in the manufacturing line have been recognised and a clear problem statement determined. This resulted in the overall reduction of wastes. What is more, a number of semi-automation solutions based on their current manufacturing capabilities have been suggested.

In some other cases, as illustrated based on the example of Company A, the suggested solutions offered by an external provider are tailored to meet the specific requirements of the company. These particular solutions are much more aligned with the firm's manufacturing system as well as much better integrated with the overall manufacturing strategy than the 'one size fits all' solutions. In the case of Company A, the modular setup of conveyor belt solutions helped the company to facilitate material handling between working station and assembly units, as well as to eliminate work-in-process inventory while utilising buffers. An additional benefit was to eliminate manual handling of the materials.

Some SMEs are very conservative about changes, as well as afraid of bringing something new to the company. Due to the limited capital/cash flow, SMEs tend to focus their attention on the day to day survival of the company rather than radical changes. This makes them think short-term. Consequently, they tend to invest in new equipment as a replacement when the machine breaks down, at the point of no-return or as part of a capacity-based expansion or a new product launch. Therefore, we would highly recommend developing a strategy of long term incremental improvements with the boundary conditions of the payback period – not longer than two years.

In regards to their manufacturing facilities improvements, SMEs usually need a support in lean automation implementation. The majority of small firms have heard of lean principles, however, the implementation process may constitute a huge challenge. With lean in mind, an enterprise can avoid automating processes that never should have been created in the first place. What is more, during SME's manufacturing facility visits, it is not unusual to observe semi-automated Kanban inventory, which according to the lean principles is useless. Lean is not manual, but the right type of automation is required. Nevertheless, a very positive observation is that most of the entrepreneurs see room for optimisation, and they are open for advancement suggestions. SMEs, if their finances allow, hire external parties to help them with the optimisation of their manufacturing facilities. Therefore, providing an open innovation environment could be a basis for establishing a common language between SMEs and automation solution providers.

In order to guide structure productivity improvements we would like to suggest a web-based platform based on technology morphology. In our view technology morphology should cover the basic needs for search automation solutions for SMEs, where they consider potential improvements in one of their manufacturing sectors. On such a platform, they should be able to search for possible solutions that exist in the market and get inspired from the relevant solutions that have addressed similar problems. Moreover, they should also be able to search for groups of specialised automation providers with existing solutions or matching competences for automating similar processes. The SMEs should also have the possibility to upload an experienced issue to the web-based open innovative platform where automation providers and other researchers in the related area can discuss the issue and give new suggestion.

Technology morphology, from an automation providers' point of view, can be a space to promote their solutions or suggestions, as well as to get familiar with SME's actual needs and expectations in regards to automation improvements. An open-based platform solution for technology morphology can also provide a space for academic researchers to extend their studies in the area of manufacturing, which is particularly relevant for small businesses. In order to create a morphology that is generic enough to cover the needs of the vast segmentation of the production businesses in the SME sector, the following criteria are suggested:

- manufacturing system
- manufacturing application groups
- specification of components of product
- complexity and level of automation.

Each criterion is divided into smaller areas or specifications, which SMEs can use to classify their particular problem or the improvement opportunity. Moreover, automation providers should be able to submit their solutions or new ideas to the posted problems. Thus, when an SME business owner searches for specific solutions through the platform, it should utilise a form of rating for displaying the search results, based on the strengths of the potential solutions in each categories, to compliance with the automation problem specifications. The platform should uncover the strengths with the use of categorisation and the connections between each section to determine the rating, which ultimately determines the prioritisation of the search results.

The web-based open innovation platform for automation should contribute to creation of creative and interactive space for both SMEs and automation providers. This platform should also help SMEs in developing their internal technical capabilities while benefiting from external capacity.

8 Conclusions

This article provides an outlook over the challenges in implementing technological improvements as well as show that a systematic innovative collaboration between SMEs with complementary capabilities in a form of project-based consultancy can help the beneficiaries in identifying and classifying the automation problems. The main automation related areas where manufacturing SMEs could leverage on external sources on knowledge are assistance in defining automation problem as well as appropriate solution and provider selection. As a potential long run solution to these issues we suggest implementation of a structured productivity improvement framework based on the technology morphology database. The accessibility of a morphological framework of technology within a web-based innovative collaboration environment could enable SMEs to get an overview over available innovative solutions as well as the way how they can benefit from it through discussion and solving their particular automation problem. This framework should provide relevant information about the possible solutions or concepts that have been tried before in the same situations. In this way SMEs can be inspired by existing ideas to make their own innovative solution for their particular automation problem.

9 Limitations and further research agenda

The first limitation relates to the application of the research method. Qualitative research methods are very useful when it comes to the exploration of a particular phenomenon, which was the case of our study. Nevertheless, our generalisation is not statistical, which means that this study could be generalised only to special contingencies. These special characteristics relate to SMEs from low-tech industry, established and conducting business under country-specific (here Danish) legislation, social and economic climate. There is a risk that under different special – and maybe also temporal – conditions, the outcome of the study could be slightly divergent. That is why future research could attempt to answer similar research questions in different country-specific environment.

Additionally, the trust formation between firms, individuals and SME's regarding to collaboration success in network needs to be studied in more detail. Future research could also address further questions related to the suggested web-based productivity improvement framework thus how to develop a morphology technology of manufacturing applications in a way that SMEs can register and classify their automation problem on the web-based open innovation platform for automation, or which features and firm specific characteristics should be taken into consideration in order to conduct reliable search for appropriate partners and solutions.

Last, but not least future research could look into the examination of the automation decision making processes and its key success criteria.

Acknowledgements

We would like to thank all people that were involved in the AutoSyd and SAFIR projects. We sincerely thank to Blue Ocean Robotics, Vækstforum, Industriens Fond and Innovationsfonden for the sponsoring of this research. Last, but not least, we also would like to thank our colleague Dr. Arne Bilberg for his encouragement and comments on the early stage of the paper.

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