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Manufacturing SME's are not worried about novel technology, but people

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Abstract: Digital transformation of the manufacturing sector is proceeding rapidly and means a drastic change especially to large companies that drive the development. Manufacturing SMEs are also required to invest in modern technologies to keep up with the competition, as they are often members of supply chains led by large companies. We present a snapshot of the current SME digital investments based on the findings of a study carried out recently as part of our H2020 project covering most of Europe. The questions we aim to answer are: what are the areas of operation where digital solutions have been implemented in, what digital applications have been implemented, what have been the initial barriers faced in the adoption of digital solutions, and what kind of risks SMEs have considered regarding their digital investments. The article provides insights for experts working in digital development for the manufacturing sector and focused on SMEs.

Keywords: Digital transformation, manufacturing, SME, ICT, barriers, investments, risks

1 Introduction and theoretical background

Digital transformation, aka digitalisation, is proliferating in the manufacturing sector. New technologies are constantly being introduced to support operations from the factory shop floor level to supply chain collaboration. Industry 4.0 is the common term for these modern manufacturing related technologies. Naturally, large manufacturing companies are driving the change and applying the latest technologies in their operations first. Manufacturing SMEs, being often part of the supply chain of the large companies, have to participate in this development as well.

Although the Industry 4.0 concept has been a hot topic already for several years, evidence of Industry 4.0 implementation in practice remains rather scarce (Bajic et al., 2020; Stentoft et al, 2021). Especially SME focused reports are missing (Stentoft et al.,

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2021; Birkel et al, 2019), and the rare ones are usually focusing on pilot studies that have limited effects on the whole company (Bajic et al, 2020). However, Ghobakhloo et al (2022) note that Industry 4.0 solutions are often scalable, enabling SMEs to initiate their Industry 4.0 transition via limited adoption of entry-level digital technologies such as social commerce platforms or cloud enterprise systems.

Regarding the barriers and challenges of Industry 4.0 adoption in the manufacturing sector, Vogelsang et al (2019) point out that the manufacturing sector companies struggle with the implementation of new technologies compared to more agile sectors like entertainment or IT, and they often underestimate the effort of digital innovation implementation. Stentoft et al (2021) emphasise that this concerns especially manufacturing SMEs. Taking the risks perspective on Industry 4.0 implementation in SMEs, Birkel et al (2019) note that SMEs perceive risks differently compared to large companies, e.g., because they do not grasp the opportunities of new business models in contrast to larger firms. Nonetheless, Birkel et al (2019) add that due to the importance of SMEs in the economy their integration is a key success factor to the concept of Industry 4.0.

According to Ghobakhloo et al (2022) SMEs' intrinsic disadvantages such as resource scarcity and skills limitation have long been recognized as barriers to innovation diffusion, and the integrative nature of Industry 4.0 technologies appears to significantly intensify these disadvantages. SMEs need to rely on external support to adopt disruptive Industry 4.0 technologies, and governments can play an important role there (Ghobakhloo et al, 2022). Government support includes addressing e.g. the financial gap by providing SMEs with tangible digital investments incentives and the digitalization policy gap through devising and enforcing supportive laws that enhance digital inclusion (Ghobakhloo et al, 2022; Estensoro et al, 2022). According to Ghobakhloo et al (2022) academia and technology providers can also play an essential role in promoting Industry 4.0 digitalization, e.g., through offering Industry 4.0 technology assistance and support, providing training and upskilling services and helping SMEs with developing their internal data culture.

This article is based on Horizon 2020 research project, Mind4Machines, which aims at supporting the digitalization of SMEs in the manufacturing sector. We strive to establish large-scale demonstrators to test a range of digital solutions to technology providers, namely SMEs and startups. This will enable the manufacturing companies engaged within the project to meet both their digitalisation and sustainability challenges. The project provides support in the form of project funding via open calls as well as coaching & mentoring support via accelerator programs (https://mind4machines.eu/). Thus, the project provides an answer to the Ghobakhloo et al (2022) call for government & academia support for SME digitalization. The article presents the findings of interviews carried out in the beginning of the project to chart the needs, drivers, and barriers of smart ICT investments in manufacturing SMEs.

The terminology regarding digitalization, IT and ICT is somewhat unclear. According to the Information Technology Glossary by Gartner, "*Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to digital business*." The same glossary defines information technology (IT) as *the common term for the entire spectrum of technologies for information processing, including software, hardware, communications technologies and related services* (Gartner 2022). Information and communications technology (ICT) has been defined by NIST to include "*all categories of ubiquitous technology used for the*

gathering, storing, transmitting, retrieving, or processing of information (e.g., microelectronics, printed circuit boards, computing systems, software, signal processors, mobile telephony, satellite communications, and networks)" (NIST 2022). Due to this vagueness in terminology and our target group being the manufacturing SMEs in different parts of Europe and Turkey, we decided to use the more established term "ICT" in our survey to provide a more common understanding of digitalisation and/or digital transformation to the respondents. Respectively, we have used the term "ICT" in chapters two and three of this article, which describe the methodology and findings of the survey, and used the term "digitalisation" in other sections of this article.

2 Research method

We based the research methodology on a structured interview covering 50 respondents in seven different countries during the timeline of September 10th to October 21st 2021. The different project partners in Bulgaria, Finland, Italy, Germany, Romania, Spain and Turkey conducted the interviews in their own countries, and we used a common questionnaire on Questback online survey service to store the responses in one platform. Each interview lasted from one to two hours and the interviewers added the responses directly to the online survey or used an offline (Microsoft Word) version of the survey to save the responses that they later transcribed into the online survey form.

The survey form consisted of four background questions, 12 research questions and a checkbox asking about the respondent agreeing to receive further communication such as a periodical newsletter from the Mind4Machines project. The background questions comprised general information about the company such as name, website, company size and manufacturing industry sector(s), and respondent information including the respondent name, job title, country, telephone number and email address. Company size was a single-choice question based on the European SME categorization, the manufacturing industry sector was a multiple-choice question and the rest of the background were open ones.

The first four research questions (questions 5-8) focused on the implementation of ICT solutions asking about the main areas of implementation (question 5) and providing further details to the response (question 6), reasons for undertaking ICT in operations (question 7) and names/topics of implemented ICT applications (question 8). Questions five, seven and eight were multiple-choice ones with an additional "please describe" field that was supposed to be filled-out in case the option was checked. Each of the three questions also had an "Other, please specify" option in case the already available options were not sufficient. Question six was an open question for providing further details to the previous question if necessary.

The next four research questions (questions 9-12) focused on the possible initial barriers that the company faced to adopt ICT solutions (question 9) as well as the technical and IT (question 10), economic (question 11) and social/organisational (question 12) risks that the company considers when planning smart ICT investments. All of the previous questions were multiple-choice ones with an "Other, please specify" option in case the already available options were not sufficient.

The last four research questions (questions 13-16) were open questions asking the respondent opinions about the implemented ICT solutions and relevant needs discovered during their implementation. The questions focused on the main benefits of the

performed ICT introduction (question 13), main changes brought about by the ICT implementation (question 14), missing and required skills necessary to improve the investment readiness level (question 15) and training needs necessary for improving the IRL and related TRL levels in the production/manufacturing domain (question 16). The open question fields had no character limitations, but we assumed that the interviewer would in any case summarise the response to the survey form.

For this article, we focused only on the most interesting survey questions and responses relating to the conference topic and therefore selected the following four as our research questions:

- what are the main areas of operation that ICT solutions have been implemented in,
- what ICT applications have been implemented,
- what have been the initial barriers faced in the adoption of ICT solutions, and
- what kind of risks SMEs have considered regarding their ICT investments.

As the barriers related questions and risk related questions were to some extent conceptually overlapping, we use them as a kind of triangulation method in analysis, comparing if they give similar or contradicting results.

In the next chapter we will describe the findings to the aforementioned research questions based on our conducted survey and try to link our results to the existing literature and other research.

3 Findings

In the following paragraphs, we present the results from the survey that provide an answer to the research questions listed in the previous chapter.

Main areas of ICT implementation

Manufacturing companies have implemented ICT solutions primarily to production (OT), which illustrates that the SMEs are strongly focusing their limited investment capabilities to their core manufacturing operations (Figure 1). The other areas or company functions have less than half of implemented ICT solutions compared to the number of production, and it is also an interesting fact that these other areas are at quite equal level. Perhaps naturally due to SMEs being smaller organizations with limited resources, the human resources function has received the least interest for ICT solution support.

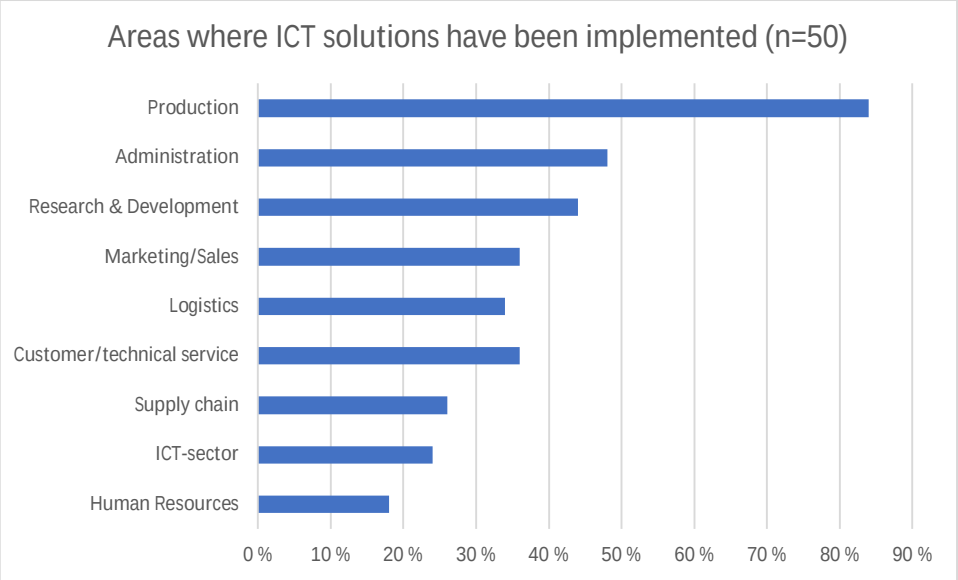

Figure 1. Main areas of ICT implementation.

Main reasons for ICT implementation

According to the respondents, the reasons for undertaking ICT in operations are mostly related to efficiency and optimization rather than new business models or market development (Figure 2). However, our study shows that manufacturing SMEs don't seem to be very interested in lean/agile technologies, although some may consider lean production methodology to be part of process optimisation and resource efficiency categories.

The open answers reveal that process optimization is pursued with ICT support to process and product traceability as well as automating manual process stages, thus enabling increase in capacity and shorter processing times. Resource efficiency is typically aimed at reducing manual work, process waste and energy consumption. The other category responses include sporadic reasons especially related to quality control improvement, which can be linked to the process optimisation category.

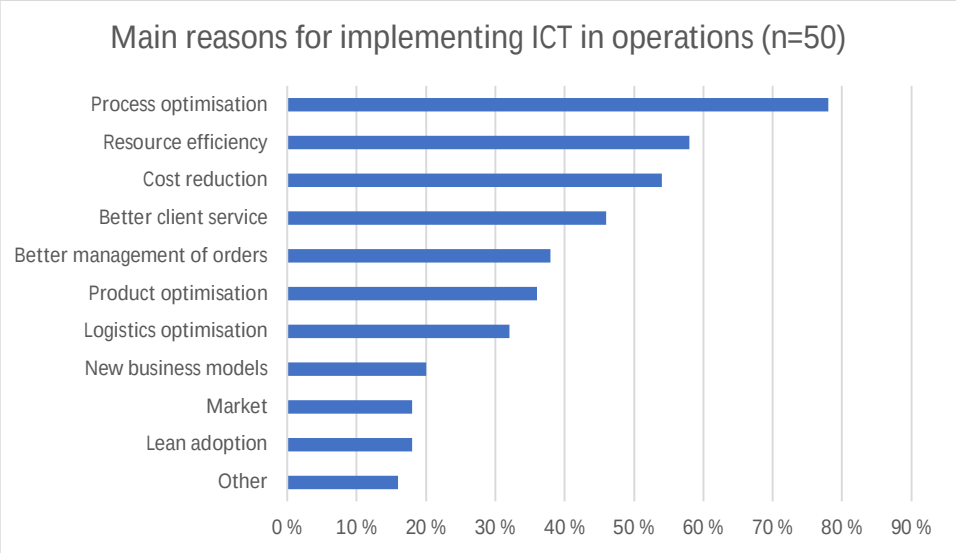

Figure 2. Main reasons for ICT implementation.

Types of implemented ICT solutions

According to the respondents, the primary ICT applications implemented are quite traditional systems like ERP, MES, IoT and CRM (Figure 3). On the other hand, the most modern and emerging solutions such as Digital Twins as well as Augmented and Virtual Reality solutions are implemented quite rarely. Solutions for e-commerce are rare as well, perhaps due to the fact that manufacturing SMEs are often sub-contractors to large companies and do not have their own products, thus limiting the need for e-commerce solutions.

The open answers provide evidence to suggest a figurative adoption path for ICT solutions: ERP systems have been used many years, MES and IoT typically only a couple of years, and the CRM system implementations have been introduced only recently. The "other" category includes mainly manufacturing equipment specific technologies such as robots and packaging automation.

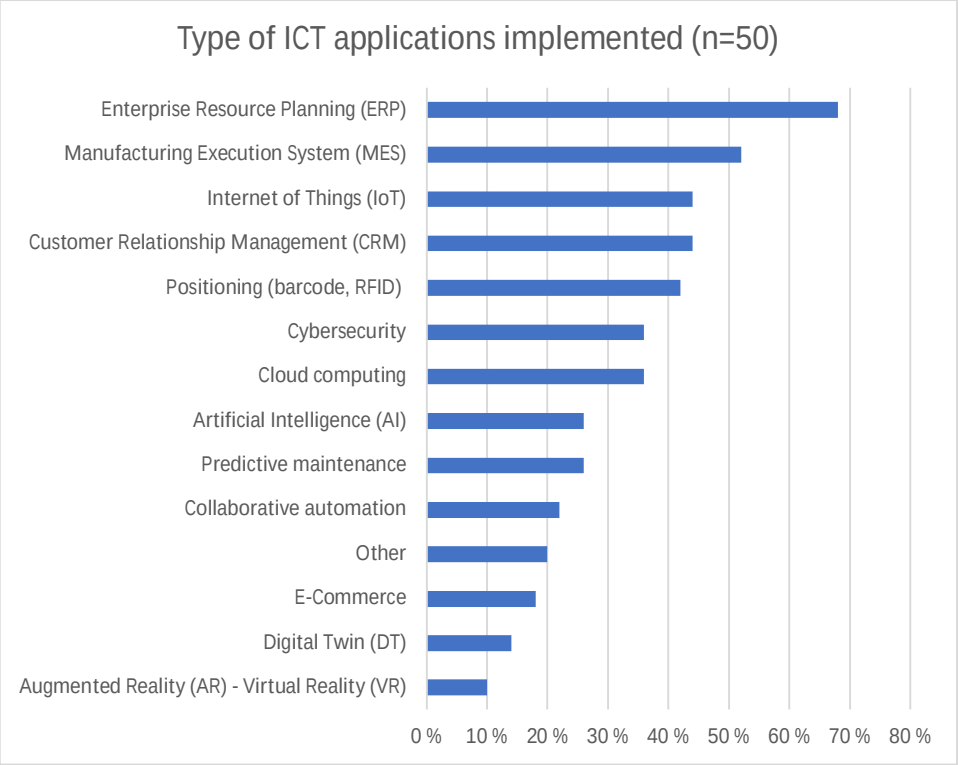

Figure 3. Types of implemented ICT solutions.

Barriers faced when adopting ICT solutions

Extant literature contains numerous studies related to the barriers to ICT adoption, but they seem to focus on SMEs in general instead of focusing on manufacturing or other specific industry sectors. Among others Arendt (2008) has studied barriers to ICT adoption in SMEs, focusing on selected regions from Europe and comparing them with the results of a similar survey carried out in the US. He used a methodology by Wielicki and Cavalcanti (2006) which rated specific barriers on a scale of 0 (no barrier) to 4 (extreme barrier) and that included barriers such as funding, knowledge and skills, relevance, personnel, standard operating procedures (SOP), strategy, software and defined information system plan (ISP). Another article by Antlova (2009) divided the barriers of ICT adoption in SMEs to four categories including technological (security, infrastructure), organisational (decision-making and finances), surrounding environment (market knowledge) and individual factors (knowledge and skills, personal relations). Our framework focused on five barriers that we considered most crucial for manufacturing SMEs and somewhat combined the technological and organisational barriers into an overall lack of skills category. The question in our survey had an “other, please specify” option in case the respondents were missing a suitable barrier, but it was only selected by a few respondents.

According to the respondents, the biggest (initial) barriers when adopting ICT solutions are high initial investment and lack of skills (Figure 4). Even though the lack of skills and people seems to be high, lack of awareness of ICT solutions is not considered

as such an issue. The "other" category consisted of three additional barriers; one related to hardware, the second related to identification of suitable suppliers and the third highlighting the complexity of solutions.

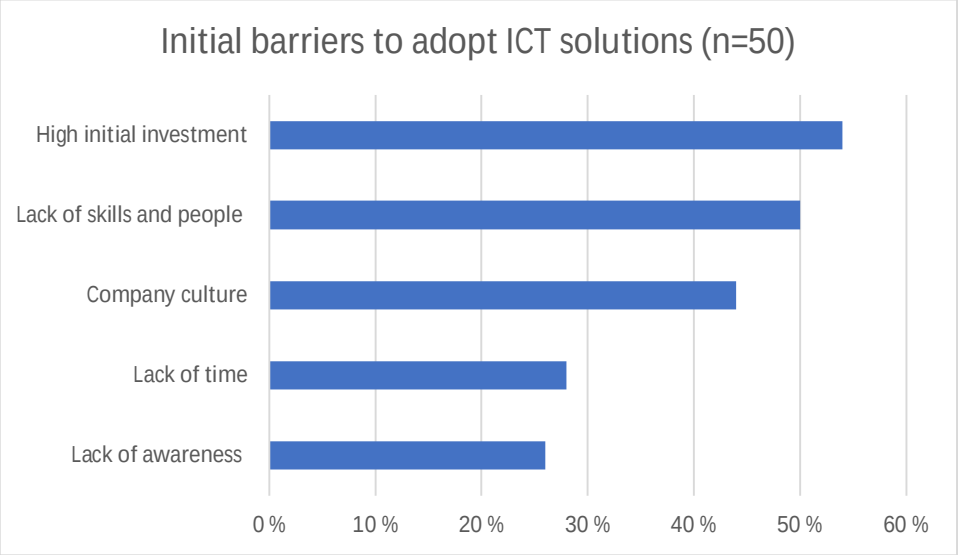

Figure 4. Barriers faced when adopting ICT solutions.

Risks considered related to ICT adoption

A slightly modified framework from Birkel et al (2019) was used for mapping the risks that companies have considered when planning smart ICT investments. Birkel et al (2019) suggest five categories of risks: 1) technical & IT risks, 2) economic risks, 3) social/organisational risks, 4) ecological risks, and 5) legal/political risks. The ecological and legal/political risk perspectives were left out from our study, as we considered them not so relevant regarding our specific focus on smart ICT utilization in manufacturing. The three risk perspectives can be briefly characterized as follows (Birkel et al, 2019). The technical risks include e.g., technical integration and information technology (IT)-related risks such as data security, handling and storage. The economic risks category includes the risks that are associated with high or false investments, as well as the threatened business models and increased competition from new market entrants. Finally, the social/organisational risk perspective considers aspects such as job losses, risks associated with organisational transformation, employee requalification, and internal resistance.

Technical & IT risks considered when adopting ICT

According to the respondents the most considered technical & IT risk risks relate to technical integration and data security issues (Figure 5). These risks can also be considered interlinked, as integrating more and more equipment and systems increases

the concerns about potential data security issues. Network infrastructure, cyber-attacks, data handling and dependency risks form the middle-group of risk considerations. Dependency risks can also be seen as a side effect of integration, as the more integrated system becomes more dependent on all its parts to stay operational. Clearly less considered risks are the ones related to standards, data storage, and cloud computing. These findings suggest that manufacturing SMEs are more concerned about the logical change towards more open and interconnected solutions than the actual technological solutions that enable them (e.g. integration vs. cloud computing).

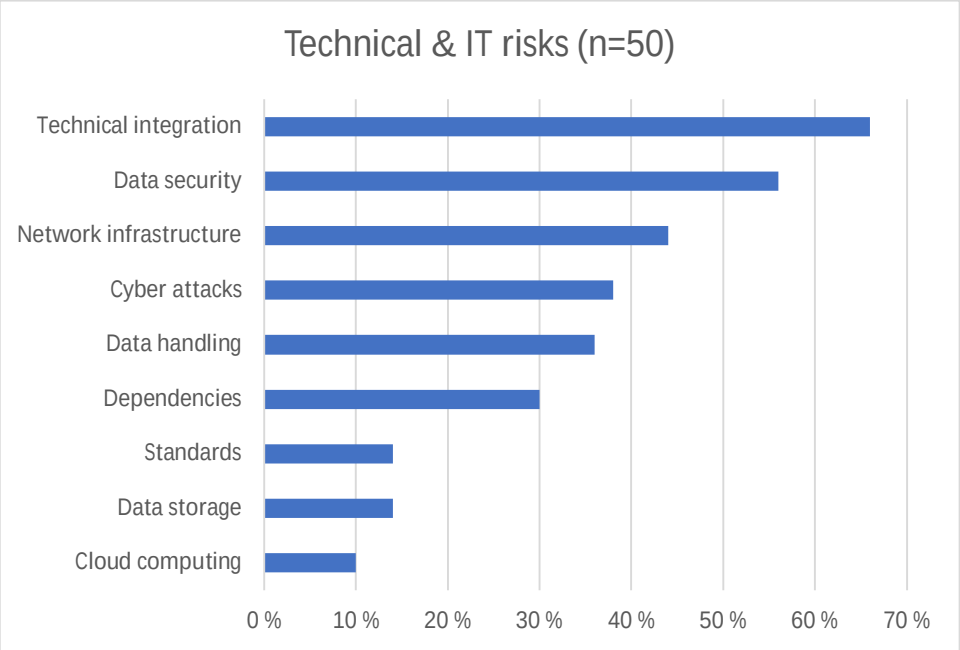

Figure 5. Technical & IT risks considered when adopting ICT.

Economic risks considered when adopting ICT

According to the respondents, the most considered economic risks relate to the time and manner of investments as well as financial risks and changing business models (Figure 6). For SMEs, due to their limited resources, the decision to invest in new technologies is a big issue. The challenge is, on the one hand, in timing the investment so that it provides benefits quickly enough, and on the other hand selecting the most relevant investment choices from the multitude of technology offerings. One respondent pointed out the risk of investing in new technology, which soon becomes obsolescent for some reason. The high ranking of financial risk considerations relate to the limited resources issue typical for SMEs and further underscore the investment decision challenge. The risk of changing business models implicate the concerns related to changing business relationships with customers, e.g. due to new data-driven and service based business models. Perhaps interestingly, the companies did not consider risks related to competition and the changing business landscape from that perspective so much.

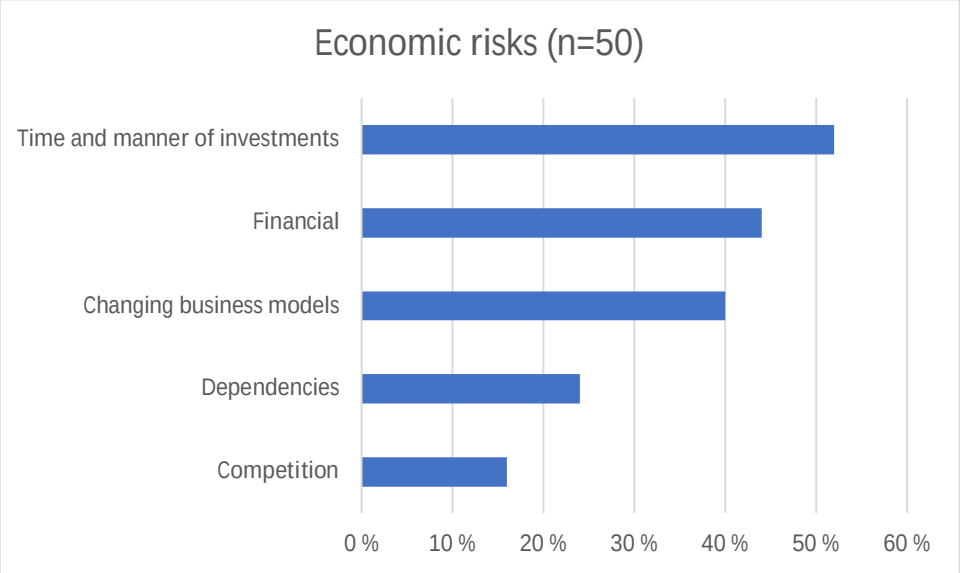

Figure 6. Economic risks considered when adopting ICT.

Social/organisational risks considered when adopting ICT

According to the respondents, the top ranking social/organisational risks considerations were the lack of qualified personnel as well as the requirement for training (Figure 7). Again, this is quite natural for SMEs struggling with limited resources. Among the required competencies and skills, respondents mentioned for example software engineering, data analytics, specific manufacturing related technology capabilities (e.g. sensor technologies), and skills related to digital twins. Additionally, some respondents made a clear distinction between competences related to the ICT solutions and specific technologies, and capabilities to implement them. The consideration of the risks related to "organizational structure and leadership" reflects this as well. Although about 25% of the respondents reported that they had implemented AI solutions, they didn't consider it as a risk to the same extent. Having less concerns about AI is somewhat interesting taking into account that there is quite a lot of discussion e.g. on its ethical use in business. Other less considered risks were job losses and manufacturing relocation due to new technology. This may be logical in the sense that these SMEs were actually looking for adding new people with ICT competences and therefore changing the location may not be a desirable option as SMEs are often well integrated in their local community.

Figure 7. Social/organisational risks considered when adopting ICT.

4 Discussion

Our study shows that manufacturing SMEs are implementing ICT actively but cautiously. The focus has been, quite naturally, on the production operations but is moving from core functions supporting systems such as ERP and MES to more advanced Industry 4.0 solutions confirming the findings of Ghobakhloo et al (2022). Our findings both from the barriers and risks perspectives suggest that the main factors that concern SMEs in their new technology investments are the risks related to the integration of systems, lack of qualified personnel, and timing the investment decision under uncertainty of new technologies. Specific new technologies do not seem to concern the SMEs so much; it seems that the integration and opening up of systems is the challenging development. This manifests itself also in the need of new competences and qualified personnel. Manufacturing SMEs have competence to manage the core manufacturing technologies and equipment, but it falls short when the integration of systems comes at play. Interestingly, this does not show as risk concerns regarding the integration technologies themselves (e.g. cloud solutions), of which there seems to be quite good awareness, but rather as a concern regarding the resulting impact of integrated processes to managing operations. That is, manufacturing SMEs seem to lack resources and competences to understand the broader systemic change and its threats and opportunities. Due to the lack of these competences, it is also challenging to make the investment decisions. The findings of our study could be concluded that the manufacturing SME's are not worried about novel technology, but instead having the competent people to understand and manage it.

Our findings on barriers and risks of digitalization in manufacturing SMEs are mostly in line with other recent studies such as Ghobakhloo et al (2022), Stentoft et al (2021), and Kumar et al (2021) with one exception. These authors suggest that SMEs lack knowledge and awareness of digitalization technologies, but our findings suggest that SMEs are aware of the technologies, or at least do not consider lack of awareness as a barrier or risk of adopting digital solutions. However, this finding may be somewhat compromised as our study also confirmed other studies' findings that SMEs see lack of personnel competences and skills being a major barrier and risk.

Our study has several limitations. First, the number of respondents (n=50) is low to make strong generalisations. When looking for frameworks to outline the questions, we noticed that there seems to be a lack of a unified view e.g. how to analyse risks in this context. Extant literature suggests several different risk or barrier categorizations, which makes it difficult to build up larger respondent databases from smaller studies such as ours, and thus reaching statistically more adequate number of responses. Secondly, the difference of respondents' interpretation and understanding of new technology concepts, e.g. IoT, AI and digital twin, affects their answers thus potentially skewing the results. Similar limitation concerns the interpretation of the risk framework as well. Thirdly, to keep the interview compact and short, we had to limit the number of questions asked and could not delve into each question in detail, which reduces the richness of research data and the strength of analysis results and conclusions. Finally, the interviewers might have also influenced the responses due to time limitations and their own knowledge. In other words, we are assuming that the open text fields of the survey form have been summarised and may contain an interpretation of the response made by the interviewer. This is the case especially with interviews that were carried out using the offline form and later transcribed into the online survey.

Our study has been done in the context of a publicly funded Horizon 2020 project to support smart ICT development for manufacturing SMEs. As such, the project can be seen as an answer to Ghobakhloo et al (2022) and Estensoro et al (2022) call for government support to SMEs struggling to take advantage of new technologies in manufacturing. This study was conducted in the early stages of the project primarily to plan the project activities. If possible, it would be interesting to study the development projects of SMEs at a later stage of the project and provide potentially more detailed insights from the field.

Acknowledgements

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