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Digital capabilities in manufacturing SMEs

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Abstract

Digital information systems are often seen as a critical source of competitive advantage in manufacturing firms. Markets offer a great variety of information systems for a wide range of purposes. However, firms' abilities to exploit these systems vary, and often it is not the technical features of the system that set the limits for the system's usefulness. The main goal of the study was to find out what kind of strengths and weaknesses manufacturing SMEs have in their digital capabilities and how their capabilities compare with firms in other businesses. To meet this goal, we made 12 evaluations in Finnish companies in South Ostrobothnia area. The DigiMat method was used for the evaluations. The secondary goal was to get feedback on how firms perceive the usability and usefulness of the evaluation method. Results show that the top priorities of development are in the capabilities related to the IT infrastructure and in the renewal and development capabilities although there is variation in their order of importance between different branches of industry. Sales and marketing, and production were also at the front. The least development is needed in HR governance and collaboration. Based on the feedback, the tool helped the personnel from different departments to form a shared understanding of development needs. The results and result visualizations also helped companies to focus their development plans.

Keywords: Digital maturity, capability analysis, SMEs

1. Introduction

Digitalization is an ongoing process that has increased performance in the manufacturing industry in several ways. In many areas, e.g. in applying artificial intelligence and the Internet of things, the digitalization is just taking its first steps in many industries, which means that digitalization is getting an even stronger change force in the coming years. This has led manufacturing firms to invest significantly in digital systems especially in countries with higher labour costs. Still, the willingness to invest in digital solutions in manufacturing does not guarantee a competitive advantage. Firms' capabilities in deploying and exploiting these systems are often more significant factors defining whether the systems bring the desired competitive edge. Lack of required capabilities leads to inefficient use of systems that may cause longer delivery times, quality problems, and extra costs. Capability to deploy and exploit digital systems is often an even more significant source of competitiveness in case of mature technologies, such as computer-aided design/manufacturing and radiofrequency identification, since these technologies are readily available to all actors and the differentiation is created mainly from the system usage.

The main objective of our study is to deepen understanding of the required capabilities to efficiently deploy and exploit digital systems in manufacturing SMEs. To meet this objective, we analysed digital capabilities in 12 Finnish SMEs in South Ostrobothnia area and identified their capability bottlenecks. Also, feedback on firms' perceptions of this kind of evaluation method was gathered. To gather capability data from firms we used a commercial DigiMat-tool that originates from research previously conducted at Tampere University.

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In the next section, we explain the theoretical background of the study focusing on the capability concept in general and on evaluating digital capability. The third section presents the research methodology by describing the DigiMat method and the real-life context of the research. In the fourth section, we present our findings by summarizing results from digital capability analysis and explain how the firms perceived the used method. In the final section, we make conclusions of our findings and give recommendations for future research.

2. Theoretical background

2.1. Capabilities in literature

The use of term *capabilities* can be challenging because of different purposes it is used in different contexts. For example, in the case of production systems, the focus can be on the technical capabilities of machines describing what is technically possible [1], but not so much on how well the machine can perform on the given task. In the management literature, capabilities are discussed usually in the context of gaining competitive advantage [e.g. 2, 3] or as a source of profitability.

Another challenge with the term capability is that it is often used interchangeably with other similar terms like competences, assets, or resources. Our use of the term has roots in strategic literature that considers capabilities as a continuation for discussions on companies' strengths and weaknesses and resource-based view (RBV) [4]. The RBV emphasizes a firm's resources as a foundation for strategy and sees resources and capabilities as a primary source for profit [2]. This differs from well-known Porter's generic strategies [5], in which the focus is more on competitors and offerings. In RBV resources and capabilities are differentiated. Resources are more static by their nature, like machines, finance, or skills. Capabilities form when resources are used together. However, this differentiation can be complex, and it is sometimes difficult to identify when resources end and capabilities begin. In recent research, the capabilities are thought to form a hierarchical system [6], in which operational capabilities are used on daily business activities and capabilities "deeper" in the organization are used for renewing the operational capabilities offering a more sustainable competitive advantage. Organizational learning [7] and dynamic capabilities [8] are examples of theories that explain these deeper capabilities.

In this study, we define capabilities as a combination of firms' processes, skills, structures, knowledge, and technology. The sufficiency of capability level depends on the intentions and objectives the firm has. Term maturity is used to describe the level of capabilities the firm has.

2.2. Evaluating digital capability

The use of maturity models and maturity measuring tools has been a typical solution to evaluate capabilities in firms. As digitalization is a growing trend in basically all fields of businesses, several tools have emerged to evaluate digital maturity, e.g. for IT Management hundreds of maturity models have been developed [9]. The maturity models are usually based on steps that describe certain states of maturity. The steps are defined in advance, and an assumption is made that to reach a certain step the steps with lesser maturity are also valid, e.g. Capability maturity model by Paul et al [10]. When the evaluation is executed, the target firm evaluates, which step of the model best describes their current situation. However, other types of maturity models also exist, e.g. MIT's annual Digital Business Global Executive Survey has eight questions with predetermined answering options and two points evaluating the maturity steps [11].

Röglinger et al. [12] found that in the maturity models, which aim to evaluate business process management, it can be challenging to identify the right maturity levels. They also noted that the models give little guidance on how to proceed to the higher maturity levels. Our empirical findings indicate the situation to be similar in the case of the models aimed at evaluating the digital maturity. Also, the existing maturity models seem to fit better for measuring the digital capability in large companies rather than in SMEs, since the maturity levels review factors that are often minor or even absent in the manufacturing SMEs, e.g. the state of IT department.

3. Research method

3.1. DigiMat method

The DigiMat method has roots in Strategic Capability Index method (SKI), which was developed at Tampere University of Technology between 2013 and 2015 in close cooperation with SMEs from the manufacturing industry [13]. SKI is meant for analyzing the overall inner capabilities of a firm, e.g. as part of the strategy process, as DigiMat is more focused and significantly lighter. Despite these differences, DigiMat-method follows the same operating logic as SKI. Both methods produce two kinds of information: (1) Current capability levels in various capability areas (2) Target levels of various capability areas.

In DigiMat, there are seven capability fields that are evaluated from the digital capability perspective: (1) Human resources governance, (2) Management and leadership, (3) Sales and marketing, (4) Development capability and renewability, (5) Production, (6) Collaboration, and (7) IT infrastructure. Concerning this article and the companies involved in it, it is important to note that even non-manufacturers have production activity. For example, planning work is the production of an engineering office, and the output is the finished plan. Thus, production does not necessarily mean manufacturing physical products.

The capability levels are defined in two steps as shown in Fig. 1. First, the basic capability level is defined. Based on the capability score from the first step, the second step has a separate capability evaluation for firms with low, medium, or high digital capability. Both steps have best practice type of arguments, whose compatibility from the firm's perspective are assessed. Higher compatibility means higher capability. The method has a total of 160 arguments.

The claims concerning the basic capabilities are related to processes in general and include, for example, the following arguments: *we have formulated a strategy that tells us where*

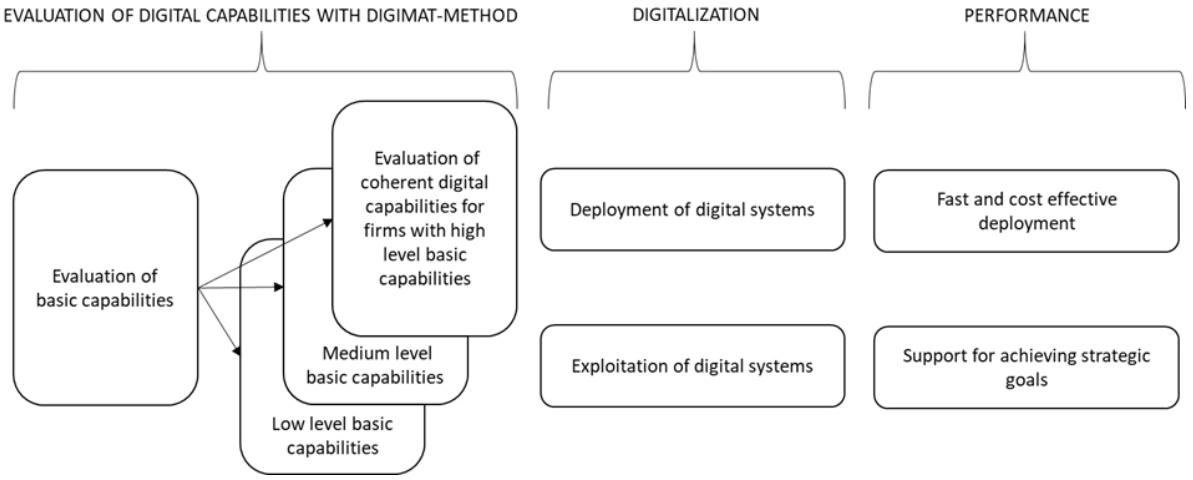

Fig. 1. DigiMat method.

we are going, how and why (management and leadership), *we utilize customer feedback effectively in developing our operations* (sales and marketing) and *the information in our IT systems is trustworthy* (IT infrastructure). The claims in the second step focus more directly on the digitalization, and the claims for companies with higher maturity levels are more challenging and comprehensive than the claims for the companies with lower maturity levels. The following examples from the claims concerning development capabilities and renewability clarify this: *we have done experiments related to digitalization* (low maturity level), and *we do active R&D collaboration with companies and/or research institutes in the field of digitalization* (high maturity level).

Evaluations are executed in workshops with one or more firm representatives and a facilitator. The target levels of each capability area are decided based on the firm's goals and intentions, e.g. if the firm aims to increase its supply network management by using new information systems, the target level of the collaboration capability should be relatively high. The participants first set the firm's target level for each capability area independently based on their perspective and business intentions. Then, they discuss the levels together and set the final consensus target levels based on a common decision. It is important that the participants with differing perspectives explain the reasons behind their choices to each other. This ensures that there is a common understanding of the targets of the company. The basic principle in the method's logic is that the firm's developmental needs cannot be directly deduced from capability levels.

The arguments are evaluated in a similar manner as the target levels: first independently and then the final evaluation is formed through discussions.

The development priorities can be deduced from the gaps between current capability levels and their target levels. Higher gap means higher development priority. For example, in the case illustrated in Fig. 2, the first development priority would be in the production-related digital capabilities.

3.2. Gathering data

We used the DigiMat method in 12 companies in South Ostrobothnia in Finland. Ten of the companies were SME's and two were slightly bigger. South Ostrobothnia is a region with a high number of small and medium-sized machine shops and equipment manufacturers. Based on a recent survey by the Confederation of Finnish Industries, it is the most entrepreneurship-friendly region in Finland [14]. Previous research shows that the companies in South Ostrobothnia grow slowly but profitably [15] and their level of digitalization is relatively low [16]. Most of the companies in our study were manufacturers but we included also some non-manufacturing companies to get a better understanding of the differences and consistencies between the practices in different industries.

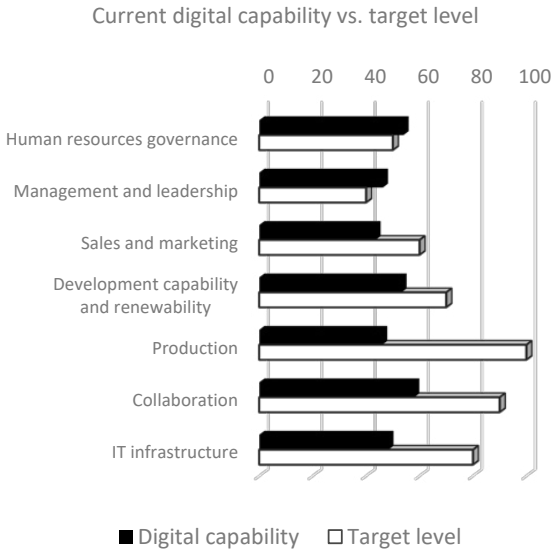

Fig. 2. Results example.

After all, the DigiMat method focuses on the processes, not on the actual products, and is compatible with the non-manufacturing industry as well. Five of the companies in our study are in metal industry, four are equipment and system manufacturers, and three are non-manufacturing companies. The sizes of the companies vary from micro to medium-sized, and the ages of the companies vary from 12 to 75 years. All of the companies had positive average annual revenue growth between the years 2015 and 2018. The growth was higher than 20 % for three companies, between 10 % and 20 % for three companies, and less than 10 % for six companies. Tables 1, 2, 3, and 4 show the profiles of the companies.

Table 1: The companies sorted based on their branch.

Branch of industry	Number of companies
Metal industry	5
Equipment and system manufacturer	4
Non-manufacturer	3

Table 2: The companies sorted based on their headcount.

Headcount	Number of companies
5–9	1
10–19	4
20–49	2
50–99	2
100–249	3

Table 3: The companies sorted based on their revenue.

Revenue (M€)	Number of companies
0.4–1	1
1–2	2
2–10	6
20–100	3

Table 4: The companies sorted based on their average annual revenue growth.

Average annual revenue growth in 2015 – 2018 (%)	Number of companies
0 – 10	6
10 – 20	3
> 20	3

We measured the digital capabilities of the companies by organizing workshops where 3 – 5 persons from the different functions of the company participated. It is recommended that different functions are represented to gain more balanced opinions: the people working in management might have flawed views of the digitalization level, the attitudes towards digitalization, and the functionality of the digital tools of the production. We organized the workshops between April 2019 and January 2020. The workshops were audio-recorded and transcribed.

Our experience was that the company representatives were eager to discuss their firm's strengths and weaknesses openly, and the atmosphere in the assessment occasions was natural. DigiMat's structure guided the discussions well. The participants formed the consensus view together for each of the claims and were ready to review their evaluation after listening to the others as the following quotations from the transcripts show:

"*I gave 4 but I accept 3. There is variation between the teams. Let's put 3.*"

"After that speech, I can raise to 8"

"My 3 is a bit fifty-fifty. There are clearly some justifications for 2, could I hear some more reasoning?"

Evaluating the claims, forming the consensus and discussing the topics deeper led to critical analysis of some of the processes. The examples include the following quotations:

"We have created structures that do not encourage developing processes in all levels".

"I wish we could take bigger risks now and then: agile experiments and quick failures. Too much safety-mindedness is not a good thing for cost-efficiency."

"I do not have a clue who is searching and from where – – No, there is nothing systematic in there."

The discussions and analysis led also to mapping of some concrete points of improvement and some action suggestions. The comments shown below demonstrate this.

"Our IT infrastructure is beginning to be full of outdated systems and there is lots of debt in that field. – – By developing systems we could get more added value and efficiency to our communications as well."

"We have lots of things we should communicate but we are not doing that. – – We are doing many great things we forget to tell outside."

"Appreciation towards the recruits is well in place but we have forgotten our old personnel."

We asked feedback about the workshop from the representatives of the companies 1 – 6 months after the workshop by email. We asked the following two questions, and the reasons for the answers:

1. Was the workshop useful?
2. Have you returned to the results or used them in planning your activity?

We gathered the feedback and made a summary of it.

4. Results

4.1. Analysis of the data

We plotted the overall digital capability versus industry to observe possible branch-specific differences in the results. Fig. 3 shows the outcome.

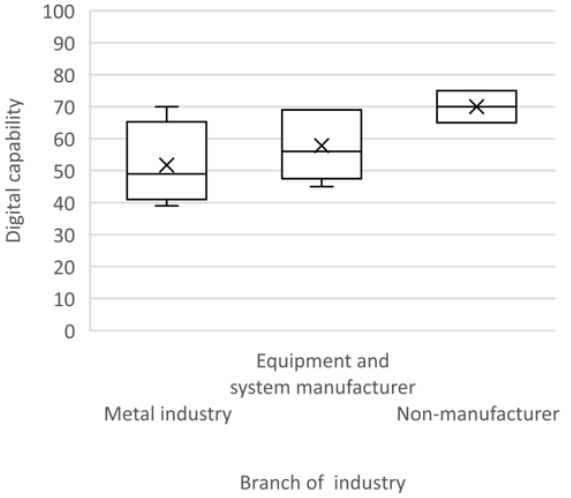

Fig. 3. Digital capability as a function of the branch of industry.

Although there are big variances in the data, the figure implies that the more digital is the product of the company, the higher is the digital capability of the company. The non-manufacturers do digital business and their digital capability is the highest. It seems that the use of different digital tools is more natural for them due to their digital production. The device and system manufacturers have electronic components, computers and software integrated into their products, and this might increase the need to utilize different digital tools in other parts of their business and thus explain their digital capabilities being the second highest. The metal industry comes the last and one possible explanation for this could lay in their traditional business field. However, it is important to note that the differences between the branches of industry are not big and that the highest ranked metal industry company had slightly higher digital capability than any of the device manufacturers. It is also worth to note that some companies might be more critical and thus the numerical evaluations may not be exactly comparable. Nevertheless, Fig. 3 suggests that there are some differences between the overall digital capabilities of the branches of industry.

We were interested in the strengths and weaknesses in the digital capabilities of the companies and the possible branch-specific differences between them. For this, we observed the current capabilities, target levels, and development priorities i.e. the gaps between the target levels and the current digital capabilities of the different fields. We focused on the descending orders of the current capabilities, target levels and development priorities instead of their numerical values. This way, all the companies got similar weight and individual high values or gaps could not dominate the results. This also eliminated the possible bias related to the varying level of criticism between the companies.

We first sorted the current capabilities of each company representing the same branch of industry in the descending order. Then, we summed the ranks of the corresponding capability fields with each other. This way, the fields with high ranks got a low sum and hence ordering the sums in ascending order gave us their order of importance. We repeated this for target levels and development priorities. Tables 5, 6, and 7 present the results.

Table 5. Current capabilities in descending order by the branch of industry.

#	Metal industry	Equipment and system manufacturer	Non-manufacturer
1	Management and leadership	Collaboration	Human resources governance
2	Collaboration	Production	Collaboration
3	Human resources governance	Sales and marketing / Human resources governance	Management and leadership
4	IT infrastructure		IT infrastructure
5	Production	Management and leadership	Sales and marketing
6	Development capability and renewability	IT infrastructure	Development capability and renewability
7	Sales and marketing	Development capability and renewability	Production

Table 6. Target levels in descending order by the branch of industry.

#	Metal industry	Equipment and system manufacturer	Non-manufacturer
1	IT infrastructure	IT infrastructure	IT infrastructure / Production
2	Sales and marketing	Production	
3	Development capability and renewability	Sales and marketing	Sales and marketing / Development capability and renewability
4	Management and leadership	Development capability and renewability	
5	Production	Collaboration	Human resources governance
6	Collaboration	Management and leadership	Management and leadership
7	Human resources governance	Human resources governance	Collaboration

Table 7. Development priorities in descending order by the branch of industry.

#	Metal industry	Equipment and system manufacturer	Non-manufacturer
1	Sales and marketing	IT infrastructure	Production
2	IT infrastructure	Development capability and renewability	IT infrastructure
3	Development capability and renewability	Production	Development capability and renewability
4	Production	Sales and marketing	Sales and marketing
5	Management and leadership	Management and leadership	Management and leadership
6	Human resources governance	Collaboration	Collaboration
7	Collaboration	Human resources governance	Human resources governance

4.2. Feedback from the Companies

We analyzed the feedback gathered from the companies 1 – 6 months after the workshop. Nine out of 10 companies that gave feedback viewed the workshop useful, and five out of those nine had utilized the data afterwards. The companies regarded the workshop as a useful discussion between the departments that helped to increase shared understanding of the present state of the company. About half of the companies, in addition, mentioned that the results help plan the future development tasks and almost all of them had already utilized them in planning. Fig. 4 summarizes the feedback. Some examples of the feedback include the following:

"*It made us think about what else we could digitalize.*"

"It gave the participants confidence that we are on the right track."

"*Based on the results, we could see clearly the sectors we needed to concentrate on developing and the priorities of the development steps.*"

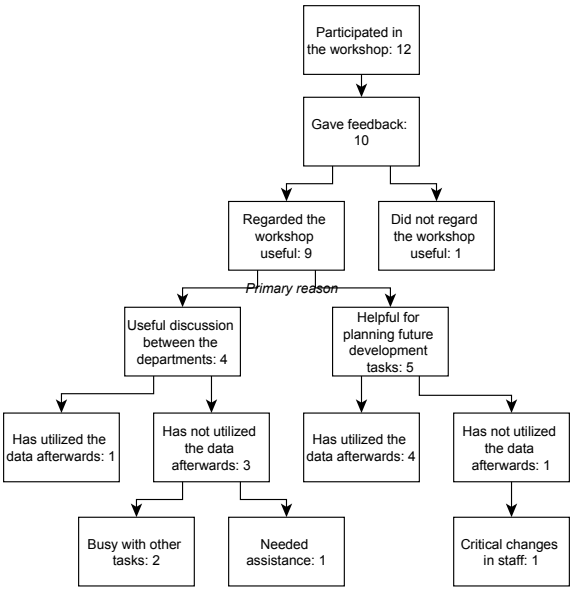

Fig. 4. Illustration of the feedback received from the companies.

5. Conclusions and discussion

Our study had two goals. First, we aimed to deepen understanding of SMEs' capabilities to deploy and exploit digital systems. The second goal was related to the DigiMat-method that was used to gather capability data from firms. We wanted to gather knowledge on how firms perceive this kind of method, and does it facilitate and support firms' development work.

Results show (Table 7) that IT infrastructure and development capability and renewability were among the most important development priorities for all the companies – in the top three for all the branches of industry. However, there were clear differences in the first priorities. Sales and marketing was the first development priority for the metal industry companies whereas it was in the fourth place for the equipment and device manufacturers and non-manufacturers. In addition, production was the first development priority for the non-manufacturers and the second development priority for the device and system manufacturers but only on the fourth place for the metal industry.

The order of the development priorities comply rather well the target levels as seen from Table 6. The top three development priorities are the capability fields with the top three target levels for the metal industry and non-manufacturers. For the equipment and system manufacturers, development capability and renewability breaks this pattern and rises from the fourth place in target levels to the second in development priorities. The explanation is seen in Table 5: development capability and renewability has the lowest current capability for equipment and system manufactures, which yields the wide gap between the target level and current level.

Management and leadership, human resource management, and collaboration were the bottom three of the development priorities for all the branches of industry. They were in the bottom three of the target levels as well with the exception of management and leadership, which was on the fourth place – just outside the bottom three – for metal industry. In addition, these three capability fields dominate the top threes of current capabilities as Table 5 shows. The exception is again management and leadership, which is only in the fifth place in the current capabilities of the device and equipment manufacturers.

There is a risk that companies concentrate on the more obvious digitalization-related development priorities such as IT infrastructure (highest target levels for all) and forget that management support and employer support are both two important drivers of digitalization as found in [17]. Focusing too much on individual technologies is common especially for the companies with low digital maturity as pointed out in [18]. Therefore, management and leadership and human resource management should not be neglected but considered important development priorities as well. However, the high current capabilities in both of these capability fields show that the companies in our study have considered them as well in their digitalization strategy. Yet, there is also a risk that values related to management, leadership, and human resources lack objectivity since the capability levels are personified so strongly with the top management, which executed the evaluations. To reduce this risk in the future, we recommend executing a personnel survey including the same arguments as DigiMat has in those three areas. By comparing top managements' results with the survey results, firms can deepen their understanding on management and personnel related matters. Indeed, this has been successfully done in some occasions with the SKI method.

As shown, our study offered insights into various digital capabilities of SMEs and suggested that there are some branch-specific differences in them. The findings in general are in line with the earlier research. Development priorities of digital transformation in manufacturing companies have been located mostly to the areas of production and IT infrastructure also in a quite recent case study [19]. Moreover, the lack of digital capabilities in sales and marketing has been recognized as a regional problem of South Ostrobothnia in earlier studies as well [16]. However, before a firm conclusion can be drawn – especially from the branch-specific differences –, more data must be gathered. We will continue using DigiMat in South Ostrobothnia to achieve this, and we will use the method in other regions of Finland with our partners to study regional differences as well.

To meet the requirements of the second goal of the study, feedback was systematically collected from participating firms. The feedback was positive with only one firm, that did not consider the method and workshop to be useful. Although the DigiMat workshops were organized free of charge, the firm representatives still had to invest several man-hours into the workshops. From this perspective, the input–output ratio should always be carefully considered when public actors organize events such as this. On the other hand, the DigiMat process is light, which lowers the risk of investing in something relatively useless from the firms' perspective. The lightness of the process also lowers the threshold to participate to the workshops.

Although the DigiMat method was well received, several companies reported that the identification of development priorities had not led to actual development activities. Reasons for this varied, but it should be noted that they were not, at least

straightly, related to the method itself. Our experiences from capability analysis with similar tools indicate the same challenge that the methods and workshops are well received but they quite rarely lead to further development. Although this study found some explanations for this, we recommend deepening understanding and finding solutions on this challenge as a future research topic. The root causes preventing firms to really benefit from analysis like DigiMat are likely to be found from various functions and activities of the firm, and thus multidisciplinary research is favorable.

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