DigiMove Analysis for Manufacturing SMEs to Identify Their Current Status and next Digitalisation Steps

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Abstract: The digitalisation level of Finnish manufacturing companies must be improved in order to remain in Finland and keep the manufacturing industry competitive. Digitalisation was found to have a positive correlation with the business result. This was discovered by analysing the digitalisation level of 43 manufacturing companies in Finland. The analysis was performed with the DigiMove matrix, which contains the following six digitalisation subjects: i) Manufacturing, ii) Products and services, iii) Digital skills of production staff, iv) Foresight, v) Customer interface, and vi) Administrative functions. It also contains five maturity levels: i) General, ii) Improved, iii) Advanced, iv) Forerunner, and v) Future opportunity. Each cell in the matrix contains the description of the expected digital solutions to be used and implemented. These descriptions were discussed in detail with each company in the workshop, and their actual level of digitalisation was jointly defined. In addition to the instant analysis map created in the workshop, each company also received recommendations for their next digitalisation steps within a week. Subsequently, 43 DigiMove statistical analyses were conducted with the companies' public financial data, and a positive correlation was found between digitalisation and the financial result.

1 INTRODUCTION

Digital transformation is sweeping across the globe, much like the current pandemic, and is affecting the manufacturing industry, too. It is evident that the manufacturing industry shall and will proceed towards Industry 4.0 and beyond. Digitalisation of the manufacturing industry is developing from the manual data management of single companies to intelligent data processing and analytics in partner networks enriched by the capabilities of artificial intelligence (Heilala et al., 2020). The long-term digitalisation goal for the manufacturing industry is for digitalisation to support all manufacturing processes and enable safe and transparent collaboration within a partner network. The European Union (EU) promotes a twin transition of the industry, combining both green values and digitalisation goals (Paasi et al., 2020) (European Comission, 2021).

The digitalisation level of Finnish manufacturing companies must be improved in order to remain in Finland and keep the industry competitive. Manufacturing is considered a technology industry by the association of Technology Industries of Finland. According to its statistics the technology industry provides direct employment to approximately 313,000 people and indirect employment to about 660,000 people, and it represents over 50% of Finland's exports. In Finland, all companies' export of goods was about €65 billion in 2019. The share of SMEs amounted to €9.4 billion, or 15%, of this total. SMEs are responsible approximately 17% of the technology industry's export of goods (Technology Industries of Finland, 2021).

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2 RELATION TO THE EXISTING THEORIES AND WORK

In this section, we will briefly look at the process of digital transformation, maturity models and the digitalisation issues within small and medium sized enterprises (SMEs).

2.1 Digital Transformation

Digital transformation (DT) is a continuous technology-driven change process of both companies and the society as a whole (Ebert & Duarte, 2018). It includes the changes in roles, ways of working and business offerings caused by adoption of digital technologies either in the company or in the operation environment. DT indicates changes occurring within several areas: i) process, ii) organisation, iii) business domain, and iv) society (Parviainen et al., 2017).

2.2 Maturity Models

Maturity has become a popular measure to evaluate the capabilities of an entity since the Capability Maturity Model (CMM) was proposed, and it has been proven in practice (Paulk et al., 1993) (Wendler, 2012). In CMMs, there are five maturity levels: Initial, Managed, Defined, Quantitatively Managed and Optimising. Maturity models have a long history, and many models applied to various topics can be found in the literature. With regard to digital transformation, there are over 20 maturity models available (Teichert, 2019).

The VTT Technical Research Centre of Finland Ltd (VTT) alone has developed three maturity tools that are available for self-assessment for non-commercial use. The tools are: DigiMaturity (Leino et al., 2017), AI maturity (Saari et al., 2019) and ManuMaturity (Saari et al., 2021). These tools help to form an understanding of the concept in question and assess current readiness and performance. Also, an immediate result graph illustrates the present state and identifies potential development needs.

In addition to the ManuMaturity tool, there are several other maturity tools developed for Industry 4.0 and the manufacturing industry (Liebrecht et al., 2021; Rauch et al., 2020) as well as applications especially for SMEs and micro-sized enterprises (Kuusisto et al., 2020).

2.3 Digitalisation and SMEs

Digital transformation provides new business possibilities, but it also sets challenges for manufacturing companies. Aside from manufacturing skills, these companies must also learn new capabilities. Current manufacturing SMEs are struggling with resource constraints and knowledge gaps that slow down their digitalisation efforts and investments. The main challenges and barriers to overcome are limited understanding, insufficient resources and gaps in bringing digitalisation into practice (Heilala et al., 2020).

The ApuaDigiin.fi web service was developed to help SMEs in proceeding with digitalisation. The service presents a four-phase digital transformation model, practical tools and methods for its exploitation, company success stories and related research results (Kääriäinen & Saari, 2020).

Franka et al. described the Industry 4.0 implementation patterns in manufacturing companies and proposed four digitalisation domains: smart manufacturing, smart products, smart working and smart supply-chain. In addition to these domains, there were general base technologies like the cloud, the internet of things, big data and analytics. The complexity level of implementation naturally grows from cloud to analytics (Frank et al., 2019)

According to an SME inquiry commissioned by VTT, less than 10% of respondents considered the introduction of new digital systems and tools. The inquiry was answered by 200 Finnish manufacturing SME decision-makers. The inquiry was conducted between November 2020 and December 2020. The inquiry asked about the kinds of digitalisation solutions companies already used and which of these solutions were in the pipeline. Based on the responses, digitalisation has already begun within companies. However, the process has occurred at a slower pace than desired. For example, of the control tools, Enterprise Resource Planning (ERP) was used by almost 90 percent of the respondents. However, Manufacturing Executing System (MES)—combining both factory automation and the production control system—are used in only one out of ten companies. Only two percent of respondents considered introducing a MES system. This result accurately describes the situation of digitalisation in the Finnish manufacturing industry. The basic systems are in use, but the actual digital leap has yet to occur. A striking feature is that less than 10% of respondents typically consider introducing new systems and tools.

It is clear that SMEs need guidance and simple tools to exploit before they can select their next digitalisation step (Kääriäinen & Saari, 2020). In addition to the existing maturity tools, we propose the DigiMove matrix. DigiMove analysis provides both

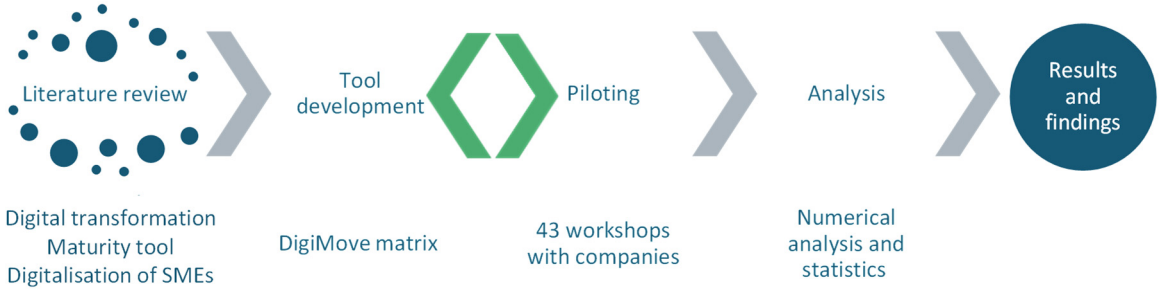

Figure 1: Research method.

the digitalisation analysis map—as maturity tools usually do—and a customised proposal for the company's next steps in digitalisation.

3 RESEARCH METHOD

In this section, we describe our research method, as shown in Figure 1. The background and a brief literature review were previously presented in Section 2. The subtitles there were digital transformation, maturity tools and digitalisation from the viewpoint of SMEs. Based on the background, we proceeded into the tool development and the result, known as the DigiMove matrix.

After 12 company assessment experiments, we clarified our definitions to make the matrix more self-sustainable and user-friendly. In the piloting phase, a total of 43 Finnish SMEs completed a workshop with us to pilot our tool and receive both their assessment results and a unique proposal to proceed with digitalisation. Finally the piloting results of companies were analysed against their financial data. The findings are presented in Section 4.

3.1 Tool Development and the DigiMove Matrix

The DigiMove matrix is used to identify the level of the company's current digital solutions and possible developments in a 1.5-hour analysis workshop. The matrix uses a five-point scale that is completed for six digitalisation subjects. The subjects of digitalisation are: i) Manufacturing, ii) Products and services, iii) Digital skills of production staff, iv) Foresight, v) Customer interface, and vi) Administrative functions. Furthermore, the five-point maturity scale has five levels for digitalisation: i) General, ii) Improved, iii) Advanced, iv) Forerunner, and v) Future opportunity (Table 1). The maturity levels and their digitalisation features are described in more detail in Table 2.

The analysis was based on the description of expected digital solutions to be used and implemented for each cell in the matrix. As an example, the description of digitalisation in the crossing of the 'Manufacturing' and 'Improved' maturity level is displayed in Table 3.

Table 1: The dimensions of the DigiMove matrix.

Digitalisation level / subject	General	Improved	Advanced	Forerunner	Future opportunity
Manufacturing					
Products and services					
Digital skills of production staff					
Foresight					
Customer interface					
Administrative functions					

Table 2: The maturity levels of the DigiMove matrix with description.

Level	Features of digitalisation
General	Most of the activities are manual, CNC controlled machines are in use, standard office programs.
Improved	Production data aggregation, optimisation, separate ERP and MES
Advanced	Robotic cells, automatic operation, ERP-enabled
Forerunner	Real-time data utilised, remote control over the network, interoperable ERP and MES
Future opportunity	Production of digital twin in partner network. Interoperable quality management and traceability with block chains. Reliable data transmission in the network (IDS concept)

Table 3: An example of the descriptions in the matrix: 'Improved' level of 'Manufacturing'.

• Separate digital manufacturing cells with CNC machines and industrial robots • IoT sensors • Multi cell monitoring • Cell-specific 24/7 automatic operation mode possible • Production is controlled by ERP

3.2 Piloting with the DigiMove Matrix

Piloting with companies was conducted with a total of 43 manufacturing companies from Finland between November 2020 and January 2021. Piloting in this case is defined as remote workshop sessions with one or more company representatives at a time. The DigiMove matrix discussion took a period of approximately 1.5 hours. Workshops were organised remotely via Microsoft Teams.

Typically, the company representative was the chief executive officer (CEO), the production director or other decision-makers. Each company had a general number of 1–3 participants. The DigiMove matrix discussions followed the same four-item agenda. The session began with a warm-up and an introduction of each person and their role. Then, facilitators clarified the purpose and the background of the session. Next, the facilitators led the discussion and digitalisation assessment of the company via DigiMove matrix row-by-row. The facilitator's role was to lead the discussion as well as guide and challenge the company representatives to evaluate the company's actual implemented digitalisation level.

The analysis was supplemented by a numeric evaluation (0-100) describing the actual realisation of the cells, which is proportional to its business importance. After the session, the mutual understanding of the digitalisation status of the company was displayed as an analysis map. In addition to the immediate result (numerical evaluation of the matrix), a verbal analysis and proposals for the next digital development steps were provided by facilitators within a week.

The DigiMove matrix pilot project was performed in close co-operation with VTT's regional agent network. VTT has 11 regional agents around Finland; these individuals are local experts who are very familiar with their region's SMEs. The selected companies are growing and internationalising, eligible for such funding as Business Finland's R&D funding, have no tax debt, and are not in debt restructuring. The sample is small but comprehensive and accurately represents Finnish manufacturing SMEs. Table 4 displays the key business numbers of the pilot companies.

Table 4: The basic numbers of the analysed companies.

Number of enterprises	43
Average turnover of the previous financial statements	€636.2 M
Aggregate result of the previous financial statements	€24.6 M
Percentage of profit on previous financial statements	4.1%
Growth rate of the previous 3-4 years	4%
Average of latest growth rate	2.7%
Sum of latest total number of staff	3860

3.3 Calculation and Statistics

This section describes how the numeric values were created and handled during the analysis. To describe the current situation at the digitalisation level, one of the six objects and five levels of the analysis tool was formed so that the objects were of equal value, but the total score of the next level always increased by one hundred. Thus, 100 points were given in the first level, 200 points were given in the second level, 300 points were given in the third level and so on. The points given to the levels in the analysis were multiplied by these coefficients and the summed result was divided by 500. On the aforementioned scale, the activity at the absolute 'General' level gives a figure of 20 and the activity at the absolute 'Future possibility' level gives a figure of 100.

Consistency in the implementation of the analyses was ensured and the scoring was harmonised among 20 companies in the first phase of the results. The companies were organised in a greatest-to-least order using their respective points. Financial data on companies over the last 3–4 years were collected from public sources, depending on the periods reported by the companies. Cumulative revenue, cumulative earnings and the cumulative earnings margin were calculated from the financial data. The conversion rate was combined with the level of digitalisation, and the correlation of the numbers was calculated.

Among the 43 companies, the data showed that there were seven companies who had achieved exceptional results during the last 2–3 periods. Aside from digitalisation, there were clearly other factors behind these numbers. These factors could come in the form of corporate acquisition, monopoly in the customer sector, temporary economic difficulties or recent heavy investments in basic technologies. The results of these companies were removed from the

data prior to the correlation calculation. The main conclusions are valid with 83% of the collected data.

4 FINDINGS

Based on the DigiMove analysis of 43 Finnish manufacturing companies, the findings are split into two topics: the digitalisation level of the Finnish manufacturing industry and its correlation with the business results. Furthermore, there are some digitalisation proposals generated during the piloting; these proposals have been generalised for this paper.

4.1 Digitalisation Level of Finnish Manufacturing Industry

From the 43 analysed manufacturing SMEs, a 'General' level of digitalisation was found among majority of the companies for the evaluation subjects of 'Manufacturing' and 'Digital skills of production staff' (see Table 5, where the highest share of companies is highlighted on each row). This indicates that most of these companies utilise manual work in their production. This was expected with complicated welding structures, where robotisation and automatization are difficult to utilise, especially in regard to small series production. It is possible, however, to digitalise other parts of the production process.

Table 5: Analysis summary of 43 company assessments.

Digitalisation level / subject	General	Improved	Advanced	Forerunner	Future opportunity
Manufacturing	34	31	22	12	1
Products and services	26	41	25	7	1
Digital skills of production staff	39	38	18	5	0
Foresight	28	36	25	9	1
Customer interface	38	35	20	7	1
Administrative functions	30	43	21	7	0

The 'Customer interface' was also evaluated to be on the 'General' level. Many small companies have only a few customers, and it is easy to communicate with them. It is easy to forget, however, that the changes in the market may have an extremely dramatic effect on the future order backlog. Small companies should never fail to look for new customers as this maintains the resilience of the business.

Among the analysed companies, the digitalisation of 'Products and services' were developed to an 'Improved' level. In many cases, the SMEs did not have their own products or a product and service combination. Oftentimes, they were working in the manufacturing ecosystem with bigger companies and manufactured products. It is evident that small companies should develop their own products to remain as competitive in the market as possible. Today, this translates to computer controlled features and functions, even with relatively simple structures and products.

Digitalisation for 'Foresight' translates to better performance of supply, which is very important for the continuity of the business. There are effective digital means available for retrieving supply chain information from the partners, but this information is not shared. In the workshops, it was often mentioned that the foresight data was not accessible to the third and fourth tier companies of the supply chain. As a result, other companies were following up to one-month old predictions despite the fact that the direct, first level suppliers could read updated foresight data directly from the customer's database. This broken link in data flow weakens the productivity of the whole network.

In the evaluations, the 'Administrative functions' were also in the 'Improved' level. In the analysing phase of these results, it was noted that these functions were not essential to the result of the business.

The digitalisation score of 36 assessed companies are displayed in Figure 2. Among these 36 companies there was none reaching the 'Future opportunity' level on each digitalisation subject. Two companies reached the 'Forerunner' level as their average digitalisation scored over 60. Fifteen companies (41%) scored between 40-60, which indicates the 'Advanced' level. Majority, nineteen companies scored between 20-40, indicating 'Improved' level of digitalisation. This shows clearly that the "digitalisation leap" has begun, but it remains in infancy under the scope of manufacturing SMEs in Finland.

4.2 Digitalisation Correlates with the Business Result

For each of the companies, the economical result for the previous 3–4 years—depending on the available data—was gathered from the public sources. The cumulative result was divided by the cumulative

turnover at the same amount of years. This average result was compared to the scored digitalisation level evaluated with the DigiMove matrix. This was chosen for the reason that the latest economical result may often include special events, investments or company trades.

The overall digitalisation result correlates positively with the average financial result of the previous 3–4 years in 83% of the companies analysed (Figure 2).

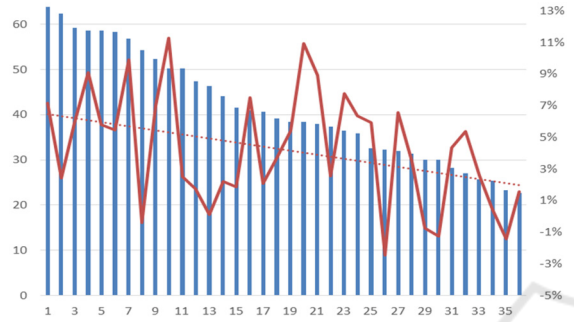

Figure 2: The overall result of the digitalisation (blue bars, left scale) and the financial result of 36 companies (red curve, right scale).

The highest correlation was found to be between the financial result and the digitalisation of 'Customer interface', 'Product and services' and 'Digital skills of the production staff'. Digitalisation of 'Administrative functions' and 'Foresight' was lowest in correlation with the financial result, as shown in Table 6.

Table 6: Correlation with the digitalisation subjects and financial result for total 36 companies.

	Correlation
Manufacturing	0.4
Products and services	0.5
Digital skills of production staff	0.5
Foresight	0.2
Customer interface	0.5
Administrative functions	0.2
Overall	0.5

It is obvious, that digitalisation is only one factor in competitiveness. However, it appears to be quite significant. There were several companies in the data, which had a relatively low level of digitalisation in the DigiMove analysis but a high level of annual profit in their business. The companies that achieved the highest results in this group specialised in the competitiveness of the product in the market or in a narrow customer segment with almost monopoly-like characteristics (e.g., defence industry, border guard). The largest financial result was for a company that specialised in a single manufacturing phase (machining).

4.3 Digitalisation Step Proposals

In addition to the immediate analysis map, each company also received a set of recommendations for the next digitalisation steps. The anonymised set of potential development actions were listed for three digitalisation subjects: i) Manufacturing, ii) Digital skills of the production staff, and iii) Customer interface (Table 7).

5 CONCLUSIONS AND FURTHER WORK

The main goal was to discover tools and processes to help manufacturing SMEs proceed with digitalisation. The target group is challenging due to the key. The idea was to increase the usability of the maturity assessment results—in addition to the status analysis map common in maturity tools—by providing a unique list of further digitalisation steps to each pilot company.

The DigiMove analysis was conducted using a matrix with six digitalisation subjects (rows) and five maturity levels (columns). The matrix was concretised with the description of expected digital solutions on each cell in the matrix. A clear matrix with facilitators made the assessment as time effective as possible. The matrix was easy to understand, and the work and discussions were effective in the workshop within minutes.

The developed DigiMove analysis was piloted with 43 manufacturing companies. The workshop was successfully performed in a remote manner. The evaluation session took about 1.5 hours from the attendees. The company representatives found the use of time useful.

The DigiMove analysis provides an analysis map of the digitalisation level of a company, and it is possible to compare the level with other companies. The mean value in the scale of 20–100 was 43 with a deviation from 23 to 64 in the evaluations (Figure 2). This means that in the Finnish manufacturing SME industry, the so-called digital leap is still in its infancy.

There is a positive correlation between the investment in digitalisation and the business results for a large number of analysed companies. Investments to the digitalisation of 'Customer

Table 7: Potential digitalisation steps for the manufacturing SMEs.

Manufacturing	Digital skills of the production staff	Customer interface
Production environment	**Information work**	**Direct contacts to customers**
Layout development and production cell formation	Digitalisation of work instructions available to everyone	Online store
Optimisation of material flows and manufacturing	Management and quality of product information and linking of tracking information to digitally manufactured products	Product customisation online
Automation	Recording changes made and hours worked directly in the systems used	Delivery time promise for a customised product
Selection of new manufacturing technologies utilising automation	**Competence**	**Faultlessness**
Introduction of production automation in manufacturing processes	Microsoft Office365 system training and access for everyone	Order formatting with EDI to EDI interface
Development of online monitoring of manufacturing cells	Capacity building of personnel to introduce automation or cobotics in production	Utilisation of software robotics in the ordering process
Utilisation of IoT sensing to support unsupervised automation	Strengthening the digitalisation skills of employees to make better use of the potential of manufacturing technologies	**Brand**
Enabling unattended automatic operation	Improving the digital capabilities of production staff in utilising IoT sensing	Up-to-date websites
Robotics	Programming of automatic machines	Website optimisation and search engine optimisation
Increasing robotics in machine service and welding	Teaching tracks to robots.	**Visibility**
Development of human-robot interaction	**Remote working**	Own channels on social media (e.g., LinkedIn, Twitter, Facebook)
Production control	Development and training of tools for on-line monitoring of manufacturing cells	News videos
Enabling co-operation between ERP and MESs (i.e., connecting production control directly to machine control)	Real-time control and monitoring of manufacturing cells via mobile	Email bots
Paperless production control	**Support schemes**	Bots
Quality and traceability	Utilising the use of 3D models on a mobile device at the installation site	Transparency in the customer interface
Digital identification of products and parts, quality assurance and traceability	Utilisation of AR welding visors or AR glasses to aid manual work	**Analytics**
Marking products with bar, RFID or QR code in production	**Situation awareness**	Dynamic graphs for mobile devices
	Manufacturing status table and KPIs available to everyone	Evaluation of potential customers

interface', 'Products and services' and 'Digital skills of production staff' are most likely to emerge in business results. When deploying this tool for the next trial in the manufacturing field, modification within 'Products and services' must be considered. The products and services in our target group may be either the company's own products, or the company may be system supplier or subcontractor in an ecosystem. Considering this role might have an effect on the overall digitalisation points of the company.

As a self-assessment tool, the DigiMove analysis is quite sensitive for skewing the company's situation. This can be prevented by using experienced external experts to facilitate the assessment workshop.

The tool was developed to help Finnish manufacturing companies to proceed in their digitalisation process. VTT is looking for opportunities to continue this work in various projects both in Finland and in Europe.

In addition to the DigiMove matrix results described above, a weak signal was intuitively detected during the study. The information flow is not transparent in supply-chains. The transparency and

flow of information in a supply-chain weakens sharply at the third and fourth subcontracting levels, even if modern IT solutions are used at the higher levels. This degrades the overall productivity of the network in particular, especially in the productivity of SMEs on the third and fourth level.

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