Effectiveness of Government Subsidies Supporting Manufacturing SMEs in Digitalization and Industry 4.0 Technology Introduction

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Abstract

Hungary in the recent decades is experiencing more and more the problems of the trap of middle-developed countries. In the recent years wages have increased substantially without fundamental improvement in productivity. The economic strategy, namely being a low wage manufacturing hub, which helped Hungary to reach the current state of welfare is losing its validity. In our research we conducted in-depth analysis of 18 project plans submitted by SMEs to a government subsidy program aiming to help SMEs to introduce digitalisation and industry 4.0 technologies into their production. We show how companies which received consulting in the program increased some of their business performance indicators. Furthermore, we identified six areas where companies see opportunity and need for improvement with industry 4.0 technologies. These are capacity shortage, labour shortage, increasing material costs, difficulties in process or performance measurement, quality issues, and information flow. We also identified how companies are trying to find solutions for the above-mentioned problems which are process improvement, investment in industry 4.0 infrastructure, identification and tracking of data in production and improvement of information flow and data visualization for data driven decision making. Our results show that most Hungarian SMEs are still at the start line of industry 4.0, since most of them need to implement a good MES (Manufacturing Execution System) and only a fraction of them is planning to implement IoT based solutions.

Introduction

Hungary in the recent decades is experiencing more and more the problems of the trap of middle-developed countries. Between 2012 and 2020 the average gross income in Hungary has increased by 83.7% (KSH, 2023) while the productivity increased only by 26% (MNB, 2020) and the GDP by 67% (KSH, 2022). Countries which exhibit the phenomenon of increasing wages combined with low productivity can lose their competitive advantage and fail to transition from middle-income range to higher income (Gill & Kharas, 2007). In Hungary this transition originally was predicted to take place in 2025 but due to COVID the transition now is predicted to 2027 (Holzhausen et al., 2021). Building strongly on being a low wage country can easily backfire even more, since more than a decade ago developed countries with traditionally strong manufacturing sector like Germany started initiatives to revive their manufacturing potential through supporting new business models based on technologies from the fourth industrial revolution or Industry 4.0 (Kagermann et al., 2011). In the last decade numerous academic literatures analysed how technologies based on digitalisation, artificial intelligence, machine learning, smart sensors and connected devices can for example enhance productivity (Pereira & Romero, 2017), improve logistic services (Nagy et al., 2018) or enhance circular economy (Kristoffersen et al., 2020). In their publication in 2014 Roland Berger Consultants have concluded, that on their Industry 4.0 readiness scale which combines the measurement of factors like production process sophistication, degree of automation, workforce readiness, innovation intensity, high value added, industry openness, innovation network and internet sophistication, Hungary reaches a score just over 2 on a scale of 5, thus being together with Slovakia, Estonia, Slovenia and Lithuania among the low readiness level group (Blanchet et al., 2014). Five years later in another study Nick et al. still find, that Hungarian companies are struggling to utilize the collected data in production and if they do (approx. 40%), they mostly use it to uncover production optimization possibilities and less than 20% of them use them to develop new product features (Nick et al., 2019).

Reducing gaps in economic development between regions of EU countries, has been a strategic goal since the Treaty of Rome (Nyikos et al., 2017). Between 2014 and 2020 more than half of the EU funding was directed through the five *European structural and investment funds (ESIF).* These funds were focused on research and innovation, digital technologies, supporting low-carbon economy, sustainable management of natural resources and small businesses. From the five funds, the *European Regional Development Fund (ERDF),* and the *Cohesion Fund (CF)* was the source of the so called GINOP (Economic Development Operative Program) in Hungary (Nyikos et al., 2017).

In this study we are trying to answer the research question, whether and how a government subsidy program has helped SMEs to understand the management and industry 4.0 concepts and technologies and to subsequently be able to incorporate the learnings into their operations. We do this by first introducing Industry 4.0 concepts, secondly presenting the structure, goal and approach of a specific subsidy program and lastly through the analysis of development plans created by the companies throughout the participation in the program.

Industry 4.0 Technologies

In this study it is not in our focus to give an extensive overview on different industry 4.0 definitions since it has already been done by many scholars and consulting companies. We need to create however a common understanding of what technologies are understood under the concept of industry 4.0 in general, so in our analysis later we can point out the differences between this and how Hungarian companies interpreted the concept. An extensive literature review from Pacchini et al. finds the most common technologies in different industry 4.0 concepts are *Internet of Things, Big Data, Cloud Computing, Cyber Physical Systems, Autonomous Robots, Additive Manufacturing and Augmented Reality* (Pacchini et al., 2019).

From our point of view, it is important see, that after the introduction of industry 4.0 concept at the Hannover Trade Fair in 2011 many countries started their own industry 4.0 strategies (Culot et al., 2020; Yang & Gu, 2021). Researchers show however, that a great portion of digitalisation projects fail already in the initialization phase (Davenport & Westerman, 2018; Gebauer et al., 2020). Despite there is a great number of definitions for industry 4.0 (Osterrieder et al., 2020; Vial, 2019) as Nick et al. point it out, the most important question for businesses, is what kind of and how big investment in such technologies is necessary, to achieve measurable impact on business performance (Nick et al., 2021).

Introduction of GINOP 1.1.3-16

The following analysis of the GINOP program is based on an interview with the president of IVSZ (IT Association of Hungary) and the program's websites https://ipar4.hu/ and https://modem4.hu/ .

The Hungarian government is aware of the low productivity problem (KSH, 2021) and low digital maturity level of the countries manufacturing sector (European Comission, 2022) and running many subsidy programs to support digitalization and help technology development at manufacturing SMEs. By channelling ERDF and CF through different GINOP programs it offers subsidies to manufacturing companies in less developed regions to support economic convergence.

A specific GINOP program (Modern Factory Program, GINOP 1.1.3-16) – coordinated by IFKA, *Industrial Development Coordination Agency* and supported by IVSZ, had been initiated to offer consultation to SMEs to help them to improving their competitiveness to accommodate to new challenges on the market by organisation renewal and technology adaptation.

According to the call of the program, the GINOP 1.1.3-16 aimed to:

- support renewal of Hungarian SMEs;
- create institutional fundaments of industry 4.0 developments;
- provide information on industry 4.0 solutions to Hungarian SMEs;
- help to accommodate to new challenges from the business environment;
- demonstrate theoretical and practical solutions through application environment;
- provide active support to help SMEs make well-grounded decisions on industry 4.0 development projects.

The program ran in two phases from 2017-2019 and from 2020-2023. Both phases were for free of charge for the participating companies. The first phase had three main objectives or stages. The first objective was to raise general awareness about industry 4.0 technologies. For this, five factories and demonstrational workshops (Budapest University of Technology, Continental, Eltec, Festo, MTA Sztaki, Roto) with complex industry 4.0 applications were selected and prepared for demonstration purposes. Participating companies had the opportunity to visit these factories, where technologies and processes related to industry 4.0 were explained and workshops were held. In the second stage, companies received a training session made of five occasions and were assigned to a mentor, who helped them with company specific advice. During these occasions companies were educated about lean management principles, business strategy, industry 4.0 related technologies and project management. On the fifth and last occasion the companies developed an approach to solve a current business problem or need. This was named *Simple Development Plan (SDP)*. The SDP was documented based on a template, which followed PDCA using an A3 methodology template originally developed at Toyota for problem solving (Liker, 2004). Approximately 100 companies created an SDP. From these SDPs the most promising ones were selected by experts at IFKA, and these companies received further support from specialised consulting companies to elaborate on them and created the DDPs (Detailed Development Plan). This step took about 30 days. The DDPs were based on the same A3 methodology template as the SDPs but with more in-depth problem and root-cause analysis, detailed solution proposals with feasibility and return on investment calculations. An initial project plan was also developed to help steering the technology or organizational development. The goal of phase one was to prepare participating companies for applying in other GINOP programs (GINOP 1.2.8 and GINOP 1.2.6) for industry 4.0 related technology investment subsidies.

The program had to be changed and a second phase was started in 2020, because the number of participating companies was considered too low by the government. Therefore, in the second phase after registration, participating companies could choose from a database of “modern factories” from different sizes (Factories of multinational companies (18 companies), SMEs (68 companies), and demonstrational university workshops (6)) all over the country in the manufacturing (59 companies) or service sector (33 companies). The participating companies could choose from these factories based on region or their interest in technology. These technologies were:

- Development of unique and innovative technologies (17 companies)
- Artificial intelligence (1 company)
- Cloud technology (3 companies)
- Intelligent energy usage (4 companies)
- Hydrogen technology (1 company)
- New materials and nanotechnology (7 companies)
- Big Data Analytics (6 companies)
- IoT and sensor technology (12 companies)
- Data collection and real time surveillance and analysis (32 companies)
- CRM (4 companies)
- 3D printing and scanning (16 companies)
- Lean principles (18 companies)
- Robotics and automation (46 companies)
- Enterprise Resource Planning (40 companies)

The visits to these *modern factories* became accepted after returning the visit evaluation questionnaire.

Next, in this phase of the program the participating companies could submit a presentation and evaluation about their development projects from the past, but maximum 1 year before the application to the GINOP 1.1.3-16.

The next step was the self-assessment based on the four pillars *organisational development, market relations and customer management, value creation processes, and business model*. The answers to this questionnaire were to be translated into the *development plan* cornerstones. Based on the self-assessment and a telephone interview with the manager of the company, the consultants at IFKA worked out development proposal package. This process took about 10-15 days. Based on this proposal the companies could create their *simple development plan (SDP)*.

Based on the *simplified development plan*, the companies could work out the *detailed development plan (DDP),* which had to consider the improvement of all four pillars. Participating companies received points for completing different stages of the program. These points could later be used in other GINOP programs to further decrease their own contribution in the complete budget of the program.

As one can see, the GINOP 1.1.3-16 did not offer direct subsidies for technology development or investment in new machinery. The program offered education on application of industry 4.0 technologies and supported companies by analysing their businesses and processes. Currently the DDPs from the first phase of the program are available. This paper analyses the DDPs from this phase to present the effectiveness of educational programs and to discover patterns of problematic areas at Hungarian manufacturing SMEs and analyse what kind of solutions they expect to be working.

Research Methodology

Firstly, the objective process and business indicators are analysed. Secondly an analysis of the DDPs is conducted to define problem and solution areas. Analysing the DDPs consisted of the following steps (Figure 1.). Firstly, the DDP was read to understand the focus points and parts were identified where the problem is elaborated *(Reading)*. Then, from these parts the main problems, identified solutions and expected outcomes were recorded into a table *(Listing problems)*. At this point the same wording was used as in the DDP. These steps were repeated for all 18 DDPs. In the next step the main problems and proposed solutions were raised onto a higher level of abstraction, and they were reworded with a more general meaning. This step was done by two independent analysts separately. In a following session, the analysts discussed their results and concluded the wording *(Proofing and consolidation)*. These general terms then were categorized *(Categorization of problems/solutions)*. Finally, the grouping was presented to two experts for validation. One expert from academia with PhD and research area digitalisation and information systems and one expert from the *IVSZ*.

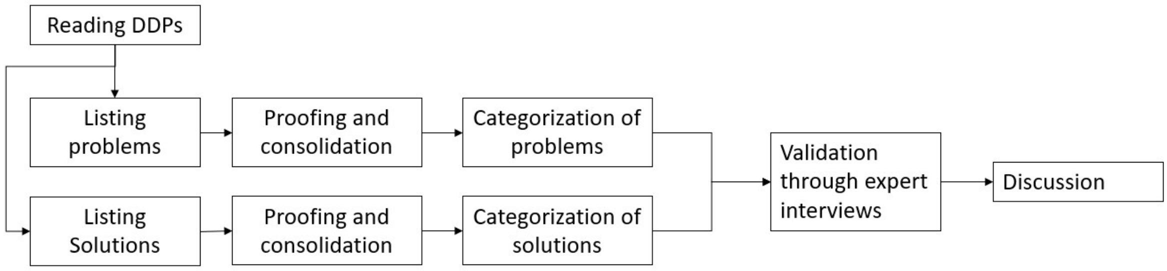

Figure 1. Steps of analysis

Results

The participating companies

The 18 companies who submitted an DDP came from wide range of industry segments like machinery manufacturing, furniture design and manufacturing or food production. Six of the eighteen companies are in the metal working or machinery industry. Most companies come from Southern Great Plain (8), followed by Western Transdanubia and Northern Great Plain (3-3). The range of yearly turnover in 2019 is from 1 million Euros to 21 million Euros. Regarding employee size the range is between 10 and 248. 12 of the 18 companies employ less, than 100 people and 6 of them less than 50.

Improvement of business performance indicators among participating companies

The comparison of the basic business performance indicators was based on data obtained from an open company database. It is important to note that most companies achieved substantial increase in these measures. The average proposed budget for a DDP was between 40,000 Euros and 2,3 million Euros, and 11 of them was under 167,000 Euros. 7 of the 18 companies were later awarded subsidies in *other* GINOP programs where the awarded budget was between 118,000 and 355,000 Euros with an average 64% subsidy intensity (on average companies had to contribute only 36% of the budget), excluding 1 company which was awarded a subsidy in the "Hungarian Multi" program reaching approx. 4 million Euros. 5 out of the 6 subsidies were awarded for investment in new equipment, and only 1 for introduction of real-time production planning and monitoring project. The subsidy winning companies increased their turnover by 65% on average and achieved 32% increase in turnover per employee. Among all companies the turnover was increased by 49% and the turnover per employee ratio by 39%.

Table 1. Participating company general business indicators. Crossed out companies are under deletion in registry.

Company Nr	Location	NUTS2	Industry	Yearly turnover 2019 (Million HUF)	Size 2019 (number of employees)	Yearly turnover 2021 (Million HUF)	Size 2021 (number of employees)
1	Komló	Southern Transdanubia	Furniture	496	26	734	33
2	Mezőtúr	Southern Great Plain	Packaging	1516	65	2039	69
3	Hódmezővásárhely	Southern Great Plain	Construction material	2636	100	3413	124
4	Csót	Central Transdanubia	Machinery	645	27	648	18
5	Szeged	Suthern Great Plain	Houshold chemical	2300	90	4348	104
6	Halászi	Western Transdanubia	Machinery	1882	88	3042	90
7	Hajdúszoboszló	Northern Great Plain	Food	200	20	360	21
8	Sopron	Western Transdanubia	Glass	1000	80	1087	42
~~9~~	~~Gyomaendrőd~~	~~Southern Great Plain~~	~~Food~~	~~75~~	~~17~~		
10	Mosonmagyaróvár	Western Transdanubia	Machinery	1496	35	3358	47
11	Dabas	Central Hungary	Metal working	576	42	925	
12	Szeged	Southern Great Plain	Textile	7798	125	11256	152
13	Szolnok	Northern Great Plain	Metal working	140	10	300	25
14	Jászapáti	Northern Great Plain	Metal working	365	46	503	49
~~15~~	~~Komló~~	~~Southern Transdanubia~~	~~Welding~~	~~570~~	~~31~~	~~229~~	~~na~~
16	Békéscsaba	Southern Great Plain	Furniture	790	182	1697	223
17	Makó	Southern Great Plain	Fireplace	4114	248	6059	398
18	Nemesvámos	Central Transdanubia	Machinery	5443	169	7000	183

Table 2. Awarded subsidies and their effect on basic business performance.

Company Nr	Project time frame (month)	Planned Project budget (million HUF)	Subsidy awarded (2019-2021)	Awarded Project topic	Subsidy (Million HUF)	Subsidy intensity %	Total subsidy budget (million HUF)	Change of Income per Employee from 2019 to 2021
1	24	880	1.2.8-20	New equipment	31.5	70%	45.00	117%
2	12	20	1.2.8-20	New equipment	61	70%	86.73	127%
3	12	35						104%
4	12	23.5						151%
5	12	50						164%
6	12	55	1.2.8-20	New equipment	71.484	70%	102.12	158%
7	12	15						171%
8	12	35						207%
~~9~~	~~12~~	~~15~~						~~n.a.~~
10	12	15	1.2.8-20	New equipment	40.369	70%	57.67	167%
11	12	40						n.a.
12	18	140						119%
13	24	470	2.1.7-15	New equipment	56.042	63.24%	88.62	86%
14	36	40						129%
~~15~~	~~24~~	~~600~~						~~n.a.~~
16	18	110	3.2.6-8	Real-time Production planning/monitoring, IoT	52.4	40%	131.00	175%
17	36	50	"Hungarian Multi"	New facility	750	50%	1500.00	92%
18	12	54						119%

Problem areas and solutions

In **Error! Reference source not found.**Table 3. one can see the rewording of mentioned problems, solutions and their categorization into *Problem groups* and *Solution groups.* We identified 6 problem categories, which are:

(1) Capacity shortage (5 companies) can occur due to increased customer demand or bottlenecks in production. Companies list also long production time or low OEE as issues. **(2) Labour shortage, labour costs (**4 companies) issues include increased costs due to increasing wages, difficulty of finding skilled workers on the labour market and limited capacity of current labour force. **(3) Material cost and material management problems** (6 companies) are caused by bad raw material management, increasing material cost and high inventory costs. **(4) Process / Performance measurement issues** (5 companies) can be traced back to missing standardized processes demanding micro-management from the owners, not sufficient production monitoring, tracking of operators or employee performance measurement. **(5) Quality problems** (3 companies) appear as problems with product quality, slow quality check processes or difficulties in tracking quality issues. **(6) Information flow** (6 companies) issues include difficulty of understanding unplanned production stops, missing knowledge management system and generally slow information flow and missing information about status of production.

To overcome these issues, companies have identified several possible solutions with the help of consultations during the programme. These solutions and their categorization to solution groups can be also seen Table 3. Under **(1) Process improvement** (9 companies) companies understood generally improving processes, introducing lean processes, PDCA, Kaizen or JIT principles. 9 out of 18 companies mentioned in their DDPs, that they would like to focus on some kind of process improvement. 8 companies also proposed solutions, which can be described as **(2) Investment in industry 4.0 capable machinery and infrastructure** (8 companies)**.** Under this term companies mentioned solutions like introducing an automatic manufacturing cell, buying a collaborative robot, welding robot, or introducing AI powered image recognition into end-of-line quality check. Also, many of the participating firms saw potential in **(3) identification and tracking of data in production** (9 companies). In this category a bottled water providing company mentioned, that they would introduce electronic product identification to be able to track their bottles which are recollected from customers for refilling. Two companies had the goal to become paperless factories, others proposed to collect data in real-time from manufacturing process. 14 out of 18 companies indicated, that they would initiate projects or invest in technologies, which would **(5) improve information flow and data visualization for data drive decision making** (10 companies)**.** These initiatives include introducing ERP or MES into production, online task management system, E-Kanban system, SCADA, or visualization of shopfloor data on management dashboard. A brief representation of problem and solution groups and the connection between them can be seen on Figure 3.

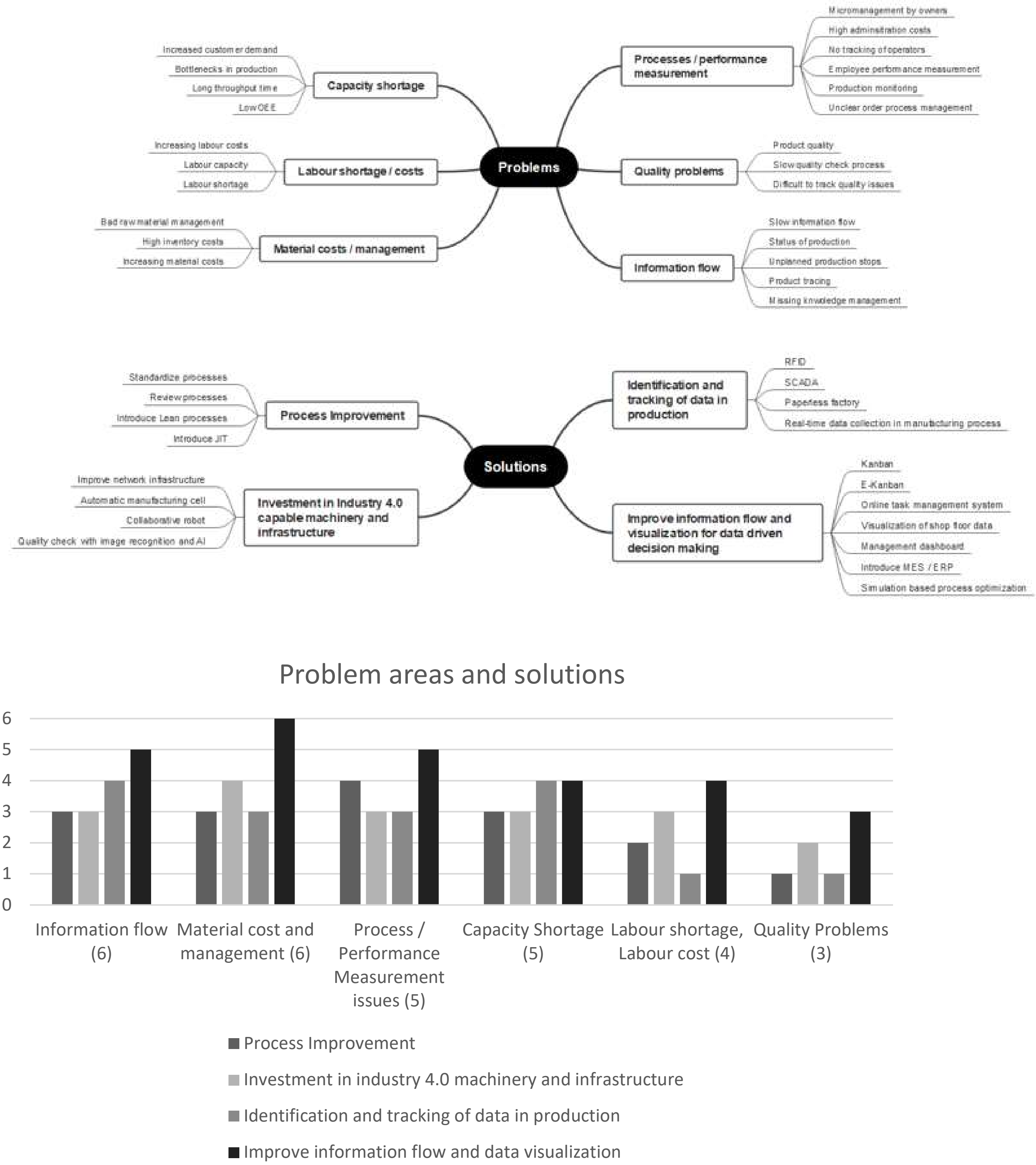

Figure 3. Problem and solution groups and their connections identified during the analysis of DDPs.

Table 3. Categorization of issues and solution from DDPs to "Problem Groups" and "Solution Groups".

Company Nr	Described Problem in RFT	Problem group		Described Solution in RFT	Solution Group
1	Capacity shortage as a result of labour market situation	2		improve lean process	1
				automatic manufacturing cell	2
2	Micro-management by owners	4		improve production process	1
	Small information about status of production	6		introduce real time machine monitoring	4
				introduce manufacturing module of ERP	4
3	Small information about status of production	6		real time manufacturing monitoring	4
				improve network infrastructure	2
				electronic product identification	3
4	High cost of administration	4		review manufacturing process	1
				improve ERP	4
				integrate project management system	4
5	Missing knowledge management	6		introduce MES	4
	Bad raw material management	3		improve network infrastructure	2
	No tracking of operators	4		electronic product identification	3
				simulation based process optimization	4
6	Increasing labour costs	2		improve lean process	1
				collaborative robot	2
				paperless factory	3
7	Bottlenecks in production	1		real time warehouse montoring	3
				introduce MES and integrate into ERP	4
				improve network infrastructure	2
8	Labour capacity	2		improve network infrastructure	2
	Low oee	1		online task management system	4
	Quality issues are hard to monitor and follow up	5		introduce e-kanban system	4
9	difficulty in tracing reusable packaging	6		introduce RFID product tracking	3
				data visualization on dashboard	4
10	Employee performance measurement	4		real-time data collection of manufacturing process	3
	Low oee	1		improve network infrastructure	2
	Raw material handling problems	3		introduce e-kanban system	4
	Unknown reason for non planned productions stops	6		online task management system	4
				process standardization	1
11	Delivery time is too long	1		Monitoring in-work material flow	4
	Quality issues	5		Visualization of shop-floor data	4
12	Unclear order process management	4		improve process management with lean tools	1
	High inventory costs	3		MES controlled digital material flow	4
13	Production volume grew faster than processes could follow	4		introduce lean production processes	1
	High inventory costs	3		Invest in welding robots	2
14	Increasing labour costs	2		introduce SCADA system	4
	Increasing material costs	3		introducing PDCA and Kaizen	1
	Quality issues	5		Introduction of JIT	1
	Production monitoring	4			
15	Unclear order process management	4		introduce MES system	4
	Slow information flow	6		paperless factory	3
				real time manufacturing monitoring	3
				improve manufacturing processes	1
16	Slow quality check process	5		Quality check using image recognition and AI	2
	Long production process	1		Data monitoring and visualization	4
17	Increased customer demand	1		expanding or upgrading ERP system	4
	Product quality	5		Integration of project tracking system and MES	4
18	Production processes management is not efficient	4		physical process review	1
	information about production is unstructured	6		expanding or upgrading ERP system	4
				Integration of project tracking system and MES	4

Conclusion

We have analysed 18 development plans submitted by Hungarian manufacturing SMEs during a consulting program financed from EU and Hungarian governmental funds. The program aimed to help companies to understand the potential in digitalisation and industry 4.0 technologies. Our research showed that 14 out of the 18 companies which received consulting, could increase their turnover by 49% and 39% their turnover per employee over the course of the two following years after the program. Furthermore, our research identified *capacity shortage, labour shortage, inventory costs, process and performance measurement, quality issues and information flow* issues as driving forces for implementation of industry 4.0 technologies. These findings confirm the driving forces identified by Horváth and Szabó (Horváth & Szabó, 2019). We also identified how Hungarian SMEs interpret industry 4.0 and see solutions for their identified problems, which are *process* *improvement, investment in industry 4.0 capable machinery and infrastructure, identification and tracking of data in production and improve information flow and visualization for data driven decision making.* The fact, that most of the participating SMEs see the biggest opportunity in process improvement and information flow improvement, and cyber physical systems, big data or additive manufacturing are not mentioned in the development plans confirms the findings of Blanchet et al from 2014, that the industry 4.0 readiness level of Hungarian SMEs is rather low (2 on scale of 5) (Blanchet et al., 2014) and seems like there has been no big step forward since then. On the other hand, educational programs even without direct subsidies for technology improvement may have beneficiary effect on the productivity level of Hungarian SMEs as seen in the sample.

Limitations and Future research

Mainly because of the qualitative nature of this study, it is not without any limitation. First of all, one cannot ignore the potential selection bias. Managers who are susceptible to new technology and innovation were more likely to participate in the program. Secondly only companies which completed successfully the first and second stages were selected to participate in the third stage which may cause the survival bias. We do not know much about individual companies who were not accepted to the third phase. To account for the selection bias a study could be useful in the time period of the program, that measures the business performance indicators of companies, which are open to new technologies and innovation but did not participate in the program.

Furthermore, even though companies from similar sector (manufacturing companies) and from similarly developed regions were selected there still might be other variables, which have some influence on their business performance.

The study analysed 18 development plans from the first phase of the program. As there were some changes in the second phase, it might be also useful to analyse development plans from participating companies from there as well. Furthermore, in-depth interviews with companies who successfully introduced industry 4.0 technologies into their production can reveal interesting insights into what challenges they faced and how they measure the impact of such technologies on business performance indicators.

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