SIMULTANEOUS USE OF ADVANCED MANUFACTURING TECHNOLOGIES AND ORGANISATIONAL CONCEPTS

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Abstract: *The main purpose of this manuscript is to map the adoption of selected organisational concepts and advanced manufacturing technologies in manufacturing companies. A further objective of our research is to analyse the relationship between organisational concepts and advanced manufacturing technology in terms of their simultaneous use. Our research is based on a sample of 141 Slovenian manufacturing companies collected through the 2022-23 European Manufacturing Survey edition. For the purpose of this research, we have used simple statistics methods. The results indicate that manufacturing companies that introduced selected organisational concepts more frequently implement selected manufacturing technologies.*

Key words: *Organisational Concept, Manufacturing Company, Advanced Manufacturing Technology, European Manufacturing Survey*

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1. Introduction and background

It is well known fact that organisational innovation is more frequently neglected in innovation theory than product and process innovations (Drejer, 2004). But according to Gallego et al. (2012) organisational innovation does have an impact on firm output, whether directly or through its interrelationship with technical innovation. Nowadays, innovation in manufacturing companies requires not only introduction of new advanced and digital technologies, but also implementing and reorganising business and process routines to remain competitive (Barañano, 2003). Lundvall and Nielsen (2002) argue that organisational innovation enables and facilitates progress in technical innovation. There are several studies pointing out that simultaneous focus on organisational and technical innovation could lead to company's competitive advantage (Evangelista and Vezzani, 2010), better learning and innovation culture (Lee et al., 2008; Rivkin, 2000), and other organisational results (Damanpour, 2014). In addition to that, Todorovic et al. (2022) argue that technologies strongly mediate the impact of organisational concepts on firm performance in terms of return on sales (ROS).

Nevertheless, there are not many studies that look for relationship between specific or selected organisational concepts and specific advanced manufacturing technologies (AMT), including digital technologies. Most studies are quite outdated, neglecting especially the use of modern Industry 4.0 and Industry 5.0 technologies. There is also a lack of studies that cover the simultaneous use of AMT and organisational concepts in terms of interdependence of specific sets of organisational concepts and advanced manufacturing and digital technologies. These two facts are a gap in scientific literature that we want to address in this manuscript.

Therefore, the main purpose of this manuscript is to map the adoption of selected AMT and organisational concepts in Slovenian manufacturing companies. Additionally, we want to test the relationship between selected organisational concepts and AMT. Based on our purpose, the structure of the remainder of the manuscript is as follows. Section 2 presents research methodology. Sections 3 and 4 give a brief description of AMT and organisational concepts in Slovenian manufacturing companies. Section 5 analyses the relationship between AMT and organisational concepts. Finally, a concluding discussion is provided for the findings, where some managerial implications, research limitation and directions for future research are given.

2. Research methodology

2.1 About European Manufacturing Survey

The data for our research is obtained from the European Manufacturing Survey (EMS), a survey organized by a consortium of European research institutes and universities. EMS is a survey on the diffusion of advanced production technologies and organisational concepts in the European manufacturing industry. It investigates technological and non-technological innovation in European industries. It focuses on fields such as technical modernisation of value adding processes, introduction of

innovative organisational concepts, international offshoring/outsourcing and back shoring of production and R&D activities, and new business models for complementing the product portfolio with innovative services. EMS includes at company level detailed information on innovation input, including R&D expenditure, innovation output such as the introduction of new products to the market, the qualification structure of the employees, and a number of control variables, such as company size, exports, the position of the company in the value chain, or characteristics of the main product and of the production process. In addition, data are collected on performance indicators such as productivity, flexibility, quality and returns (Dachs et al., 2019). The main objectives of EMS project are to find out more about the use of manufacturing and information technologies, new organisational approaches in manufacturing and the implementation of best management practices.

EMS takes place every three years. It is organized as a paper-based or electronic survey at a company level. The core questionnaire has six pages, with additional national specific questions the questionnaire may take up to 8 pages. It targets a random sample of manufacturing establishments with at least 20 employees (NACE codes from 10 to 33 in code C "Manufacturing"). The responding companies, therefore, present a multi-country cross-section of the main manufacturing industries, including producers of rubber and plastics, metal works, mechanical engineering, electrical engineering, textile and others. For preparing multinational analysis, the national data undergo a joint harmonisation procedure. Regarding the submission process, the respondent is always a top-level informant – production manager, plant manager, industrial director or Chief Executive Officer (CEO), depending on the size of each company – with a global perspective (or access to information) about the industrial and business requirements (Sartal et al., 2017).

2.2 Basic characteristics of Slovenian EMS

This research is based on the latest data from the Slovenian sample from the years 2022/23. In this latest round, 141 companies responded to the survey, which represented a response rate of over 15 %. Manufacturing companies in our research fall into the following NACE classification divisions:

- 22 – Manufacture of rubber and plastic products;
- 23 – Manufacture of other non-metallic mineral products;
- 24 – Manufacture of basic metals;
- 25 – Manufacture of fabricated metal products, except machinery and equipment;
- 26 – Manufacture of computer, electronic and optical products;
- 27 – Manufacture of electrical equipment;
- 28 – Manufacture of machinery and equipment;
- 29 – Manufacture of motor vehicles, trailers and semi-trailers;
- 30 – Manufacture of other transport equipment;
- 32 – Other manufacturing.

Table 1 present the number of companies in our database, the number of responses in each included NACE C code, response rate for each NACE code and the distribution of manufacturing companies in the total sample of respondents.

As seen, the largest NACE divisions are 25, 28 and 22. The response rates differ between NACE divisions; some of them are individually not representative. Nevertheless, 141 total responses in 2022 allowed certain statistical analysis.

NACE code C	Number of companies in database	Number of responses	Response rate NACE division	Share in total sample
22	125	22	17,6%	15,6%
23	47	9	19,1%	6,4%
24	33	7	21,2%	5,0%
25	376	45	12,0%	31,9%
26	46	11	23,9%	7,8%
27	55	6	10,9%	4,3%
28	135	25	18,5%	17,7%
29	42	11	26,2%	7,8%
30	12	0	0,0%	0,0%
32	32	5	15,6%	3,5%
Total	903	141	15,6%	100%

Tab. 1. Characteristics of EMS 2022 sample

Next, we looked at shares of companies per size. Most respondents were medium sized companies, followed by small companies. Large companies represent only 20% of our sample, small companies represent 31 % and the majority of companies in our sample are medium sized companies. Figure 1 summarizes the structure of company sizes in our sample. If we compare the results for company sizes from the newest iteration of EMS, then we can see that there are some differences. First, the share of small sized companies is nearly the same as in the previous iteration, where small companies represented 32,3% share of all companies. The share of medium sized companies that are included in the newest research has increased from 42,5% to 49% - a 6,5% increase. Lastly, the share of large companies has decreased. In 2018 large companies represented 25% of all companies but has decreased to 20% since then. This could be attributed to increased numbers of existing companies. Comparing to the last survey, the number of existing companies that are eligible to participate has increased from 778 to 903. The greatest increase in the number of existing companies is due to the companies that are in the following NACE group: Manufacturing of Metal Products, Excluding Machinery and Equipment. Since 2018 there was an almost 35% increase in companies that are classified into this category. This is followed by NACE group 22 - Manufacturing of Rubber and Plastic Products, which had only a 13% increase in eligible companies and NACE group 28 Manufacturing of Other Machinery and Equipment which had only a 5% increase in companies. This indicates favourable market conditions for these groups; however, this needs to be further researched.

We also analysed the share of manufacturers that are either OEM producers, suppliers, both, or contract manufacturers. Shares of companies based on their role are presented in Figure 2.

Share of companies that have a role of producers and suppliers is virtually the same, while only 7,8% of companies act as both the producer and suppliers. Only a miniscule number of companies have a role of contract manufacturer.

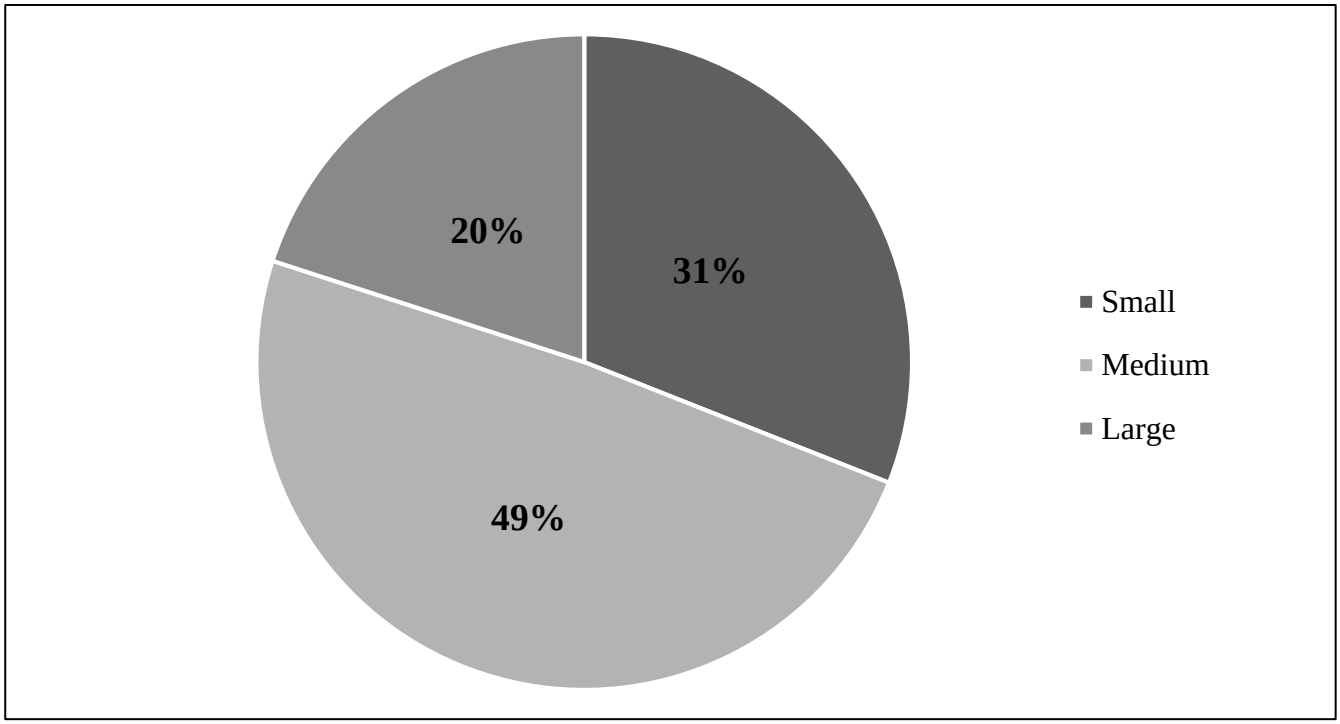

Fig. 1. Share of manufacturing companies based on size.

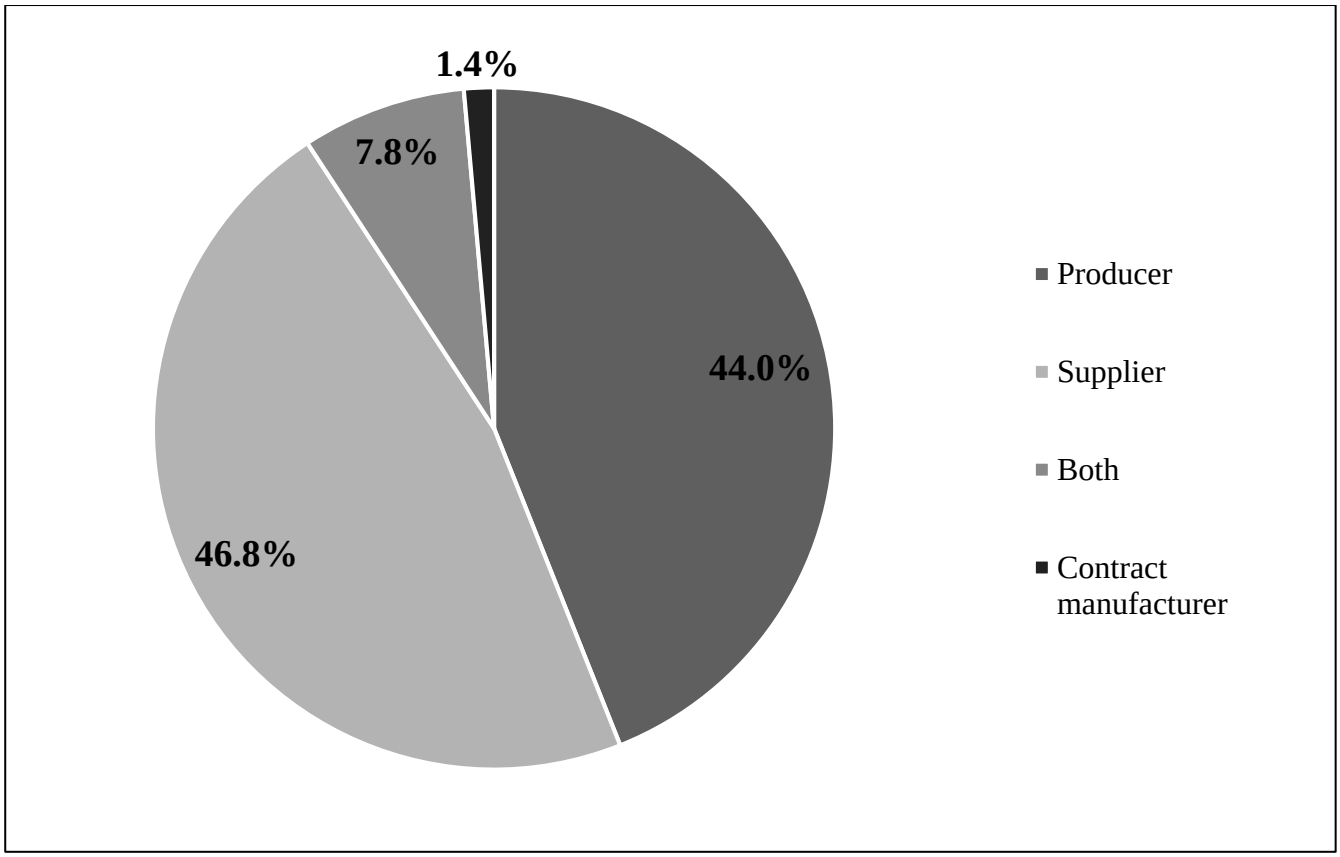

Fig. 2. Share of companies based on manufacturing role.

2.3 Adoption of AMT in Slovenian manufacturing companies

In our last EMS 2022 research round, we have analysed the use of 21 AMT. Technologies were divided into six groups:

- Production control (7 technologies);
- Automation and robots (4 technologies);
- Additive manufacturing technologies (2 technologies);
- Simulation tools and data analysis (3 technologies);
- Energy efficiency technologies (3 technologies);
- Waste recycling technologies (2 technologies).

In this manuscript, we are focusing on Industry 4.0 specific AMT from the Production control, Automation and robots, Additive manufacturing technologies, and Simulation Tools and Data Analysis technologies. Figure 3 presents a structural part of a question from EMS 2022 that deals with the diffusion of technologies and represents a core question for all our analysis.

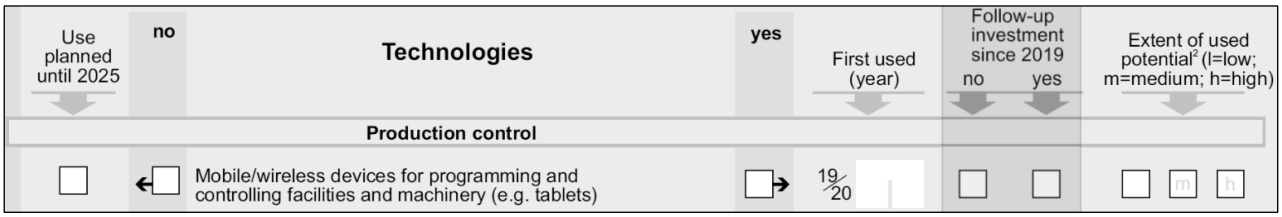

Fig. 3. Question on the use of technologies in EMS 2022.

We have analysed the technologies from several aspects:

- Frequency of technology use;
- Year of the first deployment of the technology (on average for all companies with this technology);
- The share of companies that upgraded technology in the last three years;
- The share of companies that plan to introduce the technology in the next three years;
- The level of technology use.

First, we used frequency analysis to check the frequency of use of selected technologies in Slovenian manufacturing companies (Table 2). Analysis shows that digital solutions to provide drawings, work schedules or work instructions directly on the shop floor and software for production planning and scheduling (e.g. the ERP or APS systems) are the most frequently used technologies, with instalment in around two thirds of Slovenian manufacturing companies. Mobile/wireless devices for programming and controlling machinery and/or facilities and Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI) from "Production control" group are also catching up with instalments in almost 50% of Slovenian manufacturing companies. From the IT we can also observe frequent use of software for product design simulation, while software for simulating production processes (e.g. digital twins) are still rarely implemented.

AMT	Share [%]	Planned use [%]	Upgrade [%]	Level of use
Production Control				
Mobile/wireless devices for programming and controlling machinery and/or facilities	47,5%	41,9%	56,7%	2,05
Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor	64,5%	36,0%	59,3%	2,33
Software for production planning and scheduling (e.g. ERP or APS system)	63,8%	31,4%	55,6%	2,51
Techniques for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	27,7%	30,4%	46,2%	2,17
Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI)	44,0%	16,5%	45,2%	2,32
Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	17,7%	19,8%	52,0%	2,30
Near real-time production control system (Systems of centralized operating and machine data acquisition, MES)	33,3%	33,0%	66,0%	2,49
Automation and robots				
Industrial robots for manufacturing processes (e.g. welding, cutting)	52,5%	19,4%	52,7%	2,42
Industrial robots for handling processes (e.g. inserting, sorting, packing)	38,3%	24,1%	51,9%	2,38
Mobile industrial robots (autonomously moving around the shopfloor)	5,7%	19,5%	37,5%	2,43
Collaborating robots/Cobots	9,9%	19,7%	35,7%	1,75
Additive manufacturing technologies				
3D printing technologies for prototyping (prototypes, demonstration, 0 series)	39,0%	12,8%	45,5%	2,13
3D printing technologies for manufacturing of products, components and forms, tools, etc.	23,4%	8,3%	36,4%	2,10
Simulation Tools and Data Analysis				
Software for product design simulation (e.g., product performance, reliability)	44,0%	12,7%	54,8%	2,31
Software for simulating production processes e.g. on process, line, factory level, or for supply chain – digital twins)	14,9%	16,7%	57,1%	2,22

Tab. 2. AMT adoption in Slovenian manufacturing companies.

We observed 4 types of robots. Besides industrial robots for manufacturing and handling processes we included additional subgroup of robots, namely: mobile industrial robots (e.g. AGVs) and collaborating robots/cobots. The former two robot types have been a part of manufacturing companies for a long time, while the latter robot types are gaining in their importance. When we looked at the use of industrial robots for manufacturing and handling processes together, we found that at least one type of robots is present in 64% of companies, making industrial robots the most widely used technology from our list next to ERPs and digital solutions on the shop floors.

Additive technologies have been a part of our research for several rounds. We observe two types of these technologies: 3D printing technologies for prototyping and 3D printing technologies for manufacturing. If we combine both types of additive manufacturing technologies, we can observe that at least one of them is used in around 45% of companies.

We asked manufacturing companies how many of them plan to deploy certain technologies in the period up to 2025. The "Planned use" column thus shows the share of companies that do not yet have a certain technology but want to introduce it in the mentioned period. Three years ago, in a previous survey, we found that the share of companies planning to invest in technologies in the period 2018-2021 increased significantly compared to previous research rounds. The range ranged from 10 to 35%, averaging around 20%. The results of the latest survey on the use of technologies suggest that such an increase has not occurred for most technologies. This year's survey shows that the plans of companies that do not yet own certain technologies are even more daring, with 30 to 40% of companies that do not yet have these technologies planning to have some technologies in the period up to 2025.

The column "Upgrade" is related to the share of companies that already have a certain technology and have upgraded it in the period after 2019. It can be observed that most technologies are being upgraded on an ongoing basis, on average this has happened in more than half of the manufacturing companies that use a particular technology. Digital technologies are a subject to further investments/upgrades. The share of companies that upgraded mobile industrial robots and collaborative robots is slightly smaller, which is expected given their novelty. The share of companies upgrading their technologies has increased even more compared to previous iterations of the survey, but it should be noted that this time it was a four-year time gap from the previous survey.

The level of technology use was determined according to the exploitation of the potential offered by technology, with ratings: low (1), medium (2) or high (3), whereby, of course, the possibility of subjective assessment of companies/respondents should not be ignored. The value in the "Level of use" column is the average value of the responses obtained. Again, ERP systems have the highest average usage rate with a value of 2.5 (out of a maximum of 3). This digital technology has been present in companies for a long time, so the level of use is high. There is also a high level of use for real-time production control systems, which means that companies can digitally monitor production and capture and analyse the data obtained. This fact could be very important for companies that do not yet have this technology. Even "classic" robots have a high level of use.

The lowest usage rate is expected for younger technologies such as collaborative robots (1.75), demonstrating that these technologies are still in the early stages of their use in manufacturing companies.

Figure 4 presents the use of selected technologies in the period from 2015-2018-2022. Firstly, we can clearly observe that the adoption share of majority of selected AMT has increased in the period from 2015 until 2018. The only exceptions are ERP systems and 3D technologies for manufacturing. The former already have a very high adoption frequency with around 65% through the whole observed period.

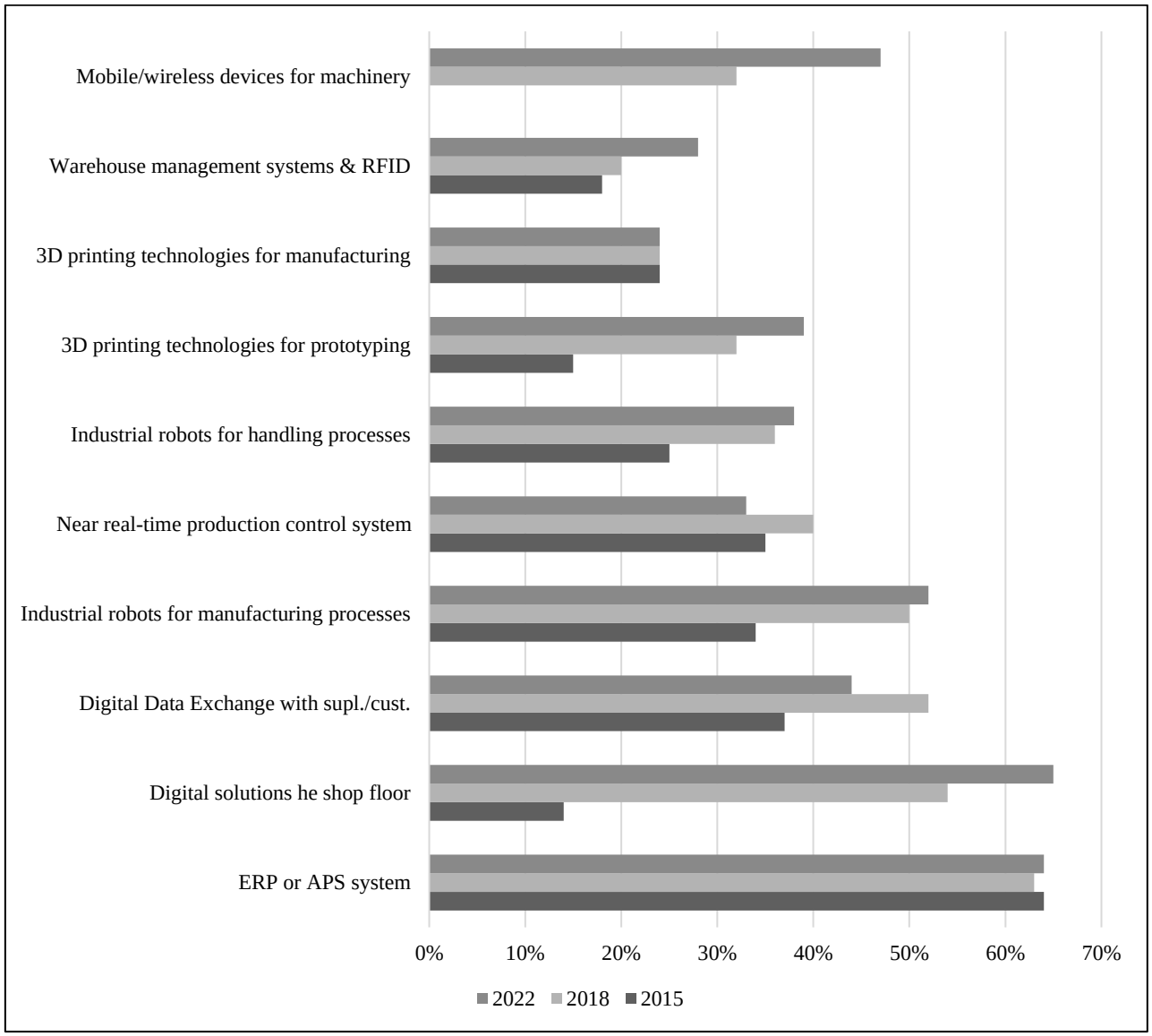

Fig. 4. Trends in using AMT in Slovenian manufacturing companies.

The increase of AMT use in the period from 2018 until 2022 in general is not so evident as for the previous period. Some technologies are (at least) stagnating in their use, while some received a major boost, especially mobile/wireless devices for programming and controlling machinery and/or facilities. Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor are also showing a steady increase in use.

We can observe an increase in the use of industrial robots manufacturing and handling processes in the period from 2015 to 2018. But if look the last period from 2018 to 2022 it seems their use is stagnating. In 20 years since we follow the use of industrial robots in Slovenia, we observed that in the period from 2003 until 2009 the use of industrial robots has doubled, but after that there was only approximately 15% of additional growth (in terms of looking the percentage of manufacturing companies that use at least one type of industrial robot). If we look at the 3D technologies and companies that use at least of two types, we can observe a substantial increase of use in the period from 2018 until 2022. According to EMS 2018 results these technologies were used in one third of the companies, in 2022 already in almost 45% of Slovenian manufacturing companies.

2.4 Adoption of organisational concepts in Slovenian manufacturing companies

The detailed presentation of organisational concepts, used in this research, was done by Palcic et al. (2020) and by Armbruster et al. (2008). In EMS 2022, we have divided 10 organisational concepts used in manufacturing companies into 2 groups:

- Organization of production (4 concepts);
- Production management/controlling (6 concepts).

For each organisational concept, we have asked for the following information:

- Use of organisational concept;
- Use planned in the upcoming period of three years;
- Year in which organisational concept has been used for the first time in factory;
- Extent of actual utilization compared to the most reasonable potential utilization in the factory: Extent of utilized potential “low” for an initial attempt to utilize, “medium” for partly utilized and “high” for extensive utilization. High utilization of an organisational concept means, for example, that it involves at least 70% of employees in the company.

All 10 organisational concepts and their adoption rate are presented in Table 3. As we can see the majority of analysed organisational concepts has an important share of implementation in manufacturing companies. The only exception are certified energy management systems. All other organisational concepts are implemented from 40% to almost 80% share. The high share of customer- or product-oriented lines/cells in the factory indicates that regardless of production type more and more manufacturing companies must focus on customer requirements and flexible production according to demanding customer wants and needs. At the same time manufacturing companies try to control their inventories and production flow with the use of different “pull principles”. More than half of manufacturing companies have introduced these two organisational concepts. “Pull principle” organisational concepts received a major push from the last EMS survey in 2019 – more than 20% increase in share of manufacturing companies that use the concept. The share of companies that use different approaches for optimizing of change-over time or reduce setup time (e.g. SMED) also increased for over 10%. On the other hand, there is a surprising finding that the share of companies who use different standardized and detailed work

instructions, which could indicate that in times of more and more customized and flexible production with the increase of automation and robotisation, the need for work instruction is not as needed or efficient.

Organisational concept	Share [%]	Planned use [%]	Level of use
Organization of production			
Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors)	61,7%	11,1%	2,35
Methods for optimizing of change-over time or reduce setup time (e.g. SMED)	47,5%	28,4%	2,11
Production controlling following the Pull principle (e.g. KANBAN, Internal zero-buffer principle)	56,0%	24,2%	2,45
Standardized and detailed work instructions (e.g. standard operation procedures SOP, Predetermined Time standards based on MOST)	40,4%	15,5%	2,11
Production Management/controlling			
Visual management and monitoring of work processes and work status on display boards in production	53,2%	37,9%	2,23
Methods of assuring quality in production (e.g. Total Quality Management procedures, certificates, continuous improvement of production processes)	78,7%	33,3%	2,34
Employee involvement in innovation development (e.g. dedicated working time, formalized sessions for idea generation)	60,3%	26,8%	2,07
Employee bonus systems for outstanding performances in production and/or innovation (e.g. profit participation, performance-related bonuses)	67,4%	15,2%	2,19
Certified environmental management system (as EN ISO 14001 or Eco-Management and Audit Scheme EMAS)	46,1%	43,4%	2,67
Certified energy management system (as EN ISO 50001 or newer version)	12,1%	38,7%	2,54

Tab. 3. Organisational concepts adoption in Slovenian manufacturing companies.

As expected, the organisational concept with the highest share is ISO 9000 quality standard. In “Production Management/controlling” group this concept is followed by two “Human resources” concepts, which indicate the importance of stimulating employees in terms of idea generation and bonus systems for outstanding

performances. The share of companies who use different visual management methods is a bit over 50%, the same as in the last research. The same observation is for both energy and environmental management systems.

The column "Planned use" presents share of companies that do not have a specific organisational concept, but are planning to introduce it in the period from 2023 to 2025. We can see that the share of companies that are planning to invest in organisational concepts in the next 3 years differs among the concepts. The highest share of planned organisational concepts is for energy and environmental management systems, which highlights the importance of sustainable and eco-friendly production in the future. A third of companies also plan to introduce visual management tools and methods as well as ISO 9000 standard. Pull principle and SMED methods are also planned in one quarter of companies that currently do not use them. Next, we looked at the extent of potential use or actual utilization (low, medium, high) of analysed organisational concepts (the last column in Table 3). All organisational concepts have an average grade between 2 and 2,5, which means that respondents believe that the use of specific organisational concept is above medium utilisation toward high utilisation of a specific concept. In general, there is a slight increase in the average grade for the utilisation rate for organisational concepts that we have examined in the previous research rounds. This fact indicates that through time manufacturing companies learn how to use the organisational concepts in terms of methods and tools more efficiently.

3. Simultaneous use of AMT and organisational concepts

We have used a simple descriptive statistic to present basic relationships between each organisational concept and each AMT. Table 4 presents results for selected organisational concepts and AMT from the group "Digital factory" and "Simulation tools and data analysis". The first column in table presents all organisational concepts. We have included only manufacturing companies that use a specific organisational concept (we have excluded those that do not use it). The other columns belong to each AMT. The numbers present the share of manufacturing companies that use a specific AMT when at the same time using organisational concept. For example, 51% of manufacturing companies that have implemented customer- or product-oriented lines/cells in their production plant also use mobile/wireless devices for programming and controlling machinery and/or facilities. The penultimate row presents the average use of a specific AMT based on the use in manufacturing companies that have implemented analysed organisational concepts. The last row on the other hand presents the general use of a specific AMT (as also seen in Table 2). For example, mobile/wireless devices for programming and controlling machinery and/or facilities are in general used in 47,5% (48%) of manufacturing companies. On the other hand, this AMT is used in 51% to 71% of manufacturing companies that have implemented analysed organisation concepts. On average, this AMT is implemented in almost 59% of manufacturing companies that use organisational concepts.

This means that the use of mobile/wireless devices for programming and controlling machinery and/or facilities is higher in manufacturing companies that also use analysed organisational concepts than its general use in all manufacturing

companies, including also those that do not use analysed organisational concepts. In the case of mobile/wireless devices for programming and controlling machinery and/or facilities the share of use of this AMT is higher in manufacturing companies with a specific organisational concept than in general population of manufacturing companies. As we have already pointed out 51% of manufacturing companies that have implemented customer- or product-oriented lines/cells in their production plant or methods of assuring quality in production (TQM) use mobile/wireless devices for programming and controlling machinery and/or facilities, and even 71% with implemented certified energy management system (ISO 50001) also use mobile solutions.

	Mobi. devi.	**Digit. solut.**	**ERP**	**Inter. logist.**	**EDI**	**PLM, PDM**	**Ctrl. syst.**	**SW – sim.**	**SW - DT**
Cells	51	76	72	35	60	24	41	54	18
SMED	60	**79**	79	45	**63**	33	**57**	52	31
Pull-p.	56	75	75	35	54	24	47	52	24
SWI	65	86	**81**	**51**	58	32	53	**56**	26
VM	59	76	73	37	56	29	53	48	25
TQM	51	71	72	32	51	22	41	48	19
EI	55	74	69	33	49	22	40	52	21
EBS	56	72	70	36	48	22	41	52	22
ISO 14001	62	74	77	39	55	28	49	57	28
ISO 50001	**71**	71	71	47	59	**47**	53	47	**47**
Ave-rage	***58,6***	***75,4***	***73,9***	***39***	***55,3***	***28,3***	***47,5***	***51,8***	***26,1***
Gen. use	***48***	***65***	***64***	***28***	***44***	***18***	***33***	***44***	***15***

Tab. 4. Organisational concepts and digital factory technologies.

A further look at Table 4 points out that the same finding is evident for all other AMT. The average share of manufacturing companies that use a specific AMT is always higher when the manufacturing company is using a specific organisational concept. The difference between average use of AMT in manufacturing companies that also uses analysed organisational concepts and the general use of selected AMT is not to be neglected (around 10% to 15%). An even more detailed look indicates that not even in one case (for any combination of a specific organisational concept and a specific AMT) the share of general use is higher than the share in observed combinations. The bold numbers in each column present the highest share of a specific AMT in a combination with one of the analysed organisational concepts.

Table 5 presents results for the groups “Automation and robotics” and “Additive manufacturing technologies”. This time we present the simultaneous use of analysed organisational concepts and more “hardware” AMT, such as different types of robots

and additive technologies. Nevertheless, the results are very similar. For all types of robots and for both types of additive technologies, the average share of manufacturing companies that use a specific type of robots or additive technologies is always higher when the manufacturing company is using a specific organisational concept. In all cases but one, the share of general use is higher than the share in observed combinations, the only exception is combination of certified energy management system (ISO 50001) and 3D printing technologies for manufacturing of products, components, parts etc. The bold numbers in each column present the highest share of a specific robot or additive technology in a combination with one of the analysed organisational concepts.

We must point out that the results for the organisational concept certified energy management system (ISO 50001) should be treated with caution as this is the only organisational concept that has a rather low implementation share, meaning that the total number of cases is a bit low. All other organisational concepts have implementation share between 45% and 79%.

	Manuf. robots	**Assem. robots**	**Mobile robots**	**Cobots**	**3D proto.**	**3D manuf.**
Cells	56	47	8	13	49	25
SMED	**63**	60	**12**	18	57	31
Pull-p.	61	51	9	17	57	**35**
SWI	60	51	**12**	19	**60**	**35**
VM	60	51	11	15	45	31
TQM	59	45	6	12	43	27
EI	61	45	8	15	49	29
EBS	61	48	8	12	46	27
ISO 14001	**63**	48	11	19	51	29
ISO 50001	59	**65**	**12**	**35**	59	18
Average	***60,3***	***51,1***	***9,7***	***17,5***	***51,6***	***28,7***
Gen. use	***53***	***38***	***6***	***10***	***39***	***23***

Tab. 5. Organisational concepts and robots and additive manufacturing technologies.

The last analysis includes only two organisational concepts, namely customer- or product-oriented lines/cells in the production plant and visual management and monitoring of work processes and work status on display boards in production. We have analysed the relationship of each organisational concept with seven digital technologies. We believe that these two organisational concepts are due to their nature and approach heavily related to technical solution in terms of digital technologies. We have performed a simple test, where we calculated the sum of implemented digital technologies in companies that have and have not implemented each of these two organisational concepts. Table 6 presents the average number of digital technologies for manufacturing companies that have and have not introduced specific organisational

concept. The number of implemented digital technologies is from 0 to maximum 7. As we can see, there is a big difference between manufacturing companies with and without selected organisational concept. For example, manufacturing companies which have introduced visual management and monitoring systems in their production plants use almost twice as many digital technologies as those companies that have not introduced this organisational concept.

	YES	**NO**
Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors)	3,6	2,0
Visual management and monitoring of work processes and work status on display boards in production	**3,8**	2,0

Tab. 6. Organisational concepts and number of digital technologies.

4. Discussion and conclusions

There are several findings in our research. Firstly, the general use of AMT is still quite dispersed. Some newer technologies, such as mobile robots, cobots, software for process simulations (digital twins), warehouse management systems (e.g. RFID) are seldom implemented as the companies still observe their potential and consider the investment in such technologies. These technologies also require skilled workers to properly introduce them and later exploit their full potential. Some other technologies that are more mature are implemented more frequently, some of them even in two thirds of manufacturing companies. The dispersion of organisational concepts is much lower. With exception of certified energy management systems other organisational concepts are implemented in at least half of the manufacturing companies.

The main aim of this manuscript was to analyse the simultaneous use of selected organisational concepts and selected AMT with a special focus on digital technologies. The results clearly indicate that the manufacturing companies which invest in specific AMT more frequently introduce specific organisational concepts. We can also look at our results from the other point of view. Our research showed that the use of selected organisational concepts implies more frequent use of AMT. We can argue that the use of AMT is somehow related to the implementation of organisational concepts, and that organisational concepts might be prerequisite for AMT adoption. This finding is additionally confirmed for the mutual relationship between specific organisational concepts and digital technologies. Our results suggest that the number of implemented digital technologies is much higher in manufacturing companies that also introduce specific organisational concept. As is the case with all research, some issues must be taken into account when considering the reliability, significance, and generalities of the results obtained. Analysed data is from one country containing 141 companies. Although the sample is not small, further research should go towards the direction of a larger sample of more countries with different levels of development and different strategies in terms of implementation of specific organisational concepts and AMT. Larger sample also enables more in-depth analysis of relationship between organisational concepts and AMT depending on the characteristics of the adopters. Larger sample of manufacturing companies will also enable the use of more

sophisticated and advanced statistical methods to test the relationship of different combinations of AMT and organisational concepts. Another important agenda is to deep more in-depth on the nature of the relationship between organisational concepts and AMT.

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