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Intelligent Production of The Future – First Results of A Survey

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***Abstract* – Witnessing the unprecedented scale and speed of industry transformation due to digitization in general and the emergence of smart solutions in all aspects of manufacturing in particular, it is well justified to deal with the question of what production of the future will look like. How intelligent will it be when the hard challenges and disruptive effects of the changes will be overcome, and what are the chances to meet the critical requirements of collaboration and cooperation, flexibility and competitiveness? What are the technological and management tools to avoid being stuck in the so-called pilot purgatory? These issues are addressed in an international survey based on a questionnaire specifically tailored to conclude to viable options and recommendations for industrial companies. The results that are mostly in conformity with those published in the literature show that there is yet a lot to do to facilitate a definite turn in the mindset of the actors and to make them realize the relevance of simultaneous and continuous cultural and technological development.**

Keywords – Manufacturing Challenges, Future Production Systems, Industrial Survey.

I. INTRODUCTION

Actual production methods are challenged by changing paradigms from a static constraint controlled mass production and mass customization to continuing personalization and regionalization of products, production, and markets. It is yet unclear what future production systems will be the most appropriate, how they will look like, and how the current, uncertain trends in manufacturing can be tackled most effectively. In the paper, the first results from a comprehensive questionnaire on 'The Intelligent Production of the Future' performed by a consortium of researchers from the Institute for Computer Science and Control (SZTAKI) and the Fraunhofer Institute for Manufacturing Engineering and Automation, IPA are outlined.

In the paper, 70 organizations (manufacturing companies, research institutes) from eight different European regions have been asked to share their impressions, describe their opinions, and rate central statements on future production systems, methodologies and trends. The paper outlines the most critical topics of future production systems and the lessons to be learned as derived during the evaluation process. The survey is composed of 24 individual questions divided into four parts. In the first part, some general information about the company are collected, primarily about its location and industry sector. In the second part, the respondents' views on future challenges and trends in manufacturing are asked. The third part is about flexible production systems, and in the last section, the respondents could give some data about themselves to get feedback on the results.

In this paper, the results regarding the following topics – included in the first part of the questionnaire – are highlighted: possible future challenges, customer requirements, and their impacts are investigated, and also, what the respondents think about smart solutions. Some of the future trends are examined, as well. Implemented initiatives, outsourcing of production processes, shifting towards a service-oriented direction, and the importance of service platforms are considered based on the responses. The most important conclusions form the other part of the questionnaire – which is about flexible production systems – are also discussed.

II. RELATED RESULTS IN THE LITERATURE

The world in which we live in is rapidly changing. The growing world population, aging society, urbanization, and the need for sustainability are just some of the major challenges that arise [1-3]. Manufacturing companies have to react to these challenges and still meet the increasing customer [4]. Customers want more and more individual

and personalized products [5] at lower prices in less time [6]. The resulting volatile and fluctuating markets increase the need for adaptable and fast reconfigurable production systems [1, 5-7].

Due to the globalization and continuing digitization of all businesses of our modern world, technological cooperation and collaboration enter the manufacturing industry bringing their methods and strategies to traditional job-shop manufacturing companies. The requirement for extreme high flexibility in production further increases and is additionally enhanced by the high competition intensity exerted, especially by the so-called Tiger States in Asia and India [8-9].

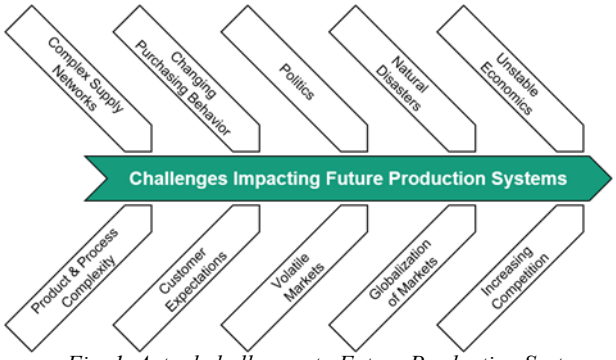

Fig. 1. Actual challenges to Future Production Systems observed

For remaining competitive in the market it requires immense efforts from traditional manufacturing companies to adapt their current business models according to their customers' changing needs [10] Fig. 1. gives an overview of actual challenges observed that affect manufacturing companies.

Nyhuis et al. defined six different technological enablers [4] to meet the changing demands in manufacturing engineering. The goals derived for this end are various and countless. Some sample examples set in parallel to the main enabling technologies can be seen in Fig. 2.

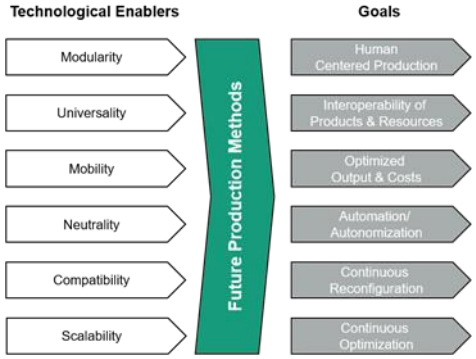

Fig. 2. Enabling technologies to meet the goals of modern production

Given the fact that new technologies enclose disruptive potential and that the speed of technological development accelerated ever faster in recent years, alternative production methods are required that allow mass production for individualized products in a lot-size of just one. Due to the restrictions of conventional production methods such as Dedicated Manufacturing Lines (DML) or Flexible Manufacturing Systems (FMS), with regard to their flexibility and corresponding scope concerning the technological enabling technologies, alternative production methods receive increasing attention [5, 11-17]. Matt introduced the term of continuous re-initialization and periodic reconfiguration to master the complexity in manufacturing operation [18]. Approaches to improve existing production methods are the continuous function-based reconfiguration of workstations and processing sequences like the matrix production [13] or Reconfigurable Manufacturing Systems (RMS) [19].

However, it is so far unclear what future production systems will look like and what will be the most promising production system. On the one hand, new technologies enable more flexibility in resource utilization and allow to meet customers' expectations at a very high level. On the other hand, the uncertainty of future trends and market developments imposes a particular risk on the implementation of these - in most cases - expensive technologies.

III. DESCRIPTION OF THE METHOD

Based on the foundations described in the previous paragraphs, it is essential to evaluate challenges, goals, and options thoroughly in order to ensure future success in production methodology. Within this paper, the first results from a comprehensive questionnaire on "The intelligent production of the future" performed by a consortium of researchers from the Institute for Computer Science and Control (SZTAKI), EPIC InnoLabs Nonprofit Ltd (EIL) and Fraunhofer Society are outlined. In this survey, stakeholders and peers from more than 70 companies and research institutions spread over six different European countries have been asked to share their experiences, describe their opinions, and rate various theses concerning future production concepts, methodologies, and trends. The paper presents the most important topics encountered and the lessons learned when evaluating the survey.

The survey "The intelligent production of the future" is composed of 24 individual questions. The structure of the questionnaire and the focus of the different parts are highlighted in Table 1.

Part	Name	Description	Questions
I	General questions about the organization	Collecting some basic information about the organization and participant	1-6
II	Future challenges and trends	Gathering details on challenges the Organization faces currently or in the future. Assessing countermeasures already put in place or planned to be	7-15
III	Flexible production systems	Assessing the potential of new production systems regarding the solution of the challenges encountered above	15-23
IV	Feedback	Contact details (to send feedback on the results if asked for)	23-24

A. General questions about the organization

In the first part of the survey, *I General questions about the organization,* general information is collected about the organization. At this point, essential data about the geographical location, branch, and primary mode of operation are gathered, which will serve to classify organizations in later steps. This introductory part includes details about the participants filling in the survey, e.g., regarding their position within the organization.

B. Future challenges and trends

The second part, *II Future challenges and trends,* aims in a first step, to identify the most significant threats affecting the operation currently by using the following questions:

- What are the biggest challenges concerning your factory?
- Which of the following customer requirements affect your company in connection with the product?
- What are the areas within your company that will be impacted most by the requirements marked in the previous question?

In a second step, to learn about the initiatives are intended to cope with the challenges mentioned before:

- Do you have implemented initiatives to cope with the challenges mentioned above?
- To what extent are the following smart solutions already in use in your production?
- How will the outsourcing of production processes develop in the future?
- Are you planning to move your manufacturing sites due to strategic considerations, e.g., cost efficiencies?
- Do you expect your business model to shift towards a more service-oriented direction?
- How important will service platforms be for your company in the future?

C. Flexible production systems

The third part, *III Flexible production systems,* represents the core of this survey. The main goal of this part is the assessment of the potential for any new production systems may offer in regard to the the chance to solve the challenges stated in the previous section. The following questions were used:

- How would you evaluate the following technologies regarding their potential towards flexibility?
- Could modular production cells be beneficial for your production process?
- How can the flexible linkage of production cells facilitate the production process?
- Would a flexible communication architecture within production be beneficial to you?
- Would the continuous, autonomous reconfiguration of the production layout be beneficial for you?

D. Feedback

The last part, *IV Feedback,* gathers contact details about the organization and the respondent in order to distribute the results (part optional).

IV. RESULTS AND DISCUSSIONS

The first part of the questionnaire contains questions about the company, primarily about its location and industry sector. As mentioned in the introduction, the respondents of the survey are typically manufacturing SMEs engaged in mass and series production. Regarding their value creation focus, they are almost equally distributed between R&D and Manufacturing.

The second part of the survey focuses on future challenges and manufacturing trends. In this part, where the questions are marked with an asterisk (*), the respondents could give a rating on a 1..10 scale; 1..3 was considered as of low, 4..7 as of moderate, and 7..10 as of high importance/impact/benefit (depending on the specific question).

As Fig. 3. highlights, more than half of the participants claim that their most significant challenges today are growing competition and lack of a qualified workforce. Nevertheless, only less than 10% think that missing local cooperation discriminates their business.

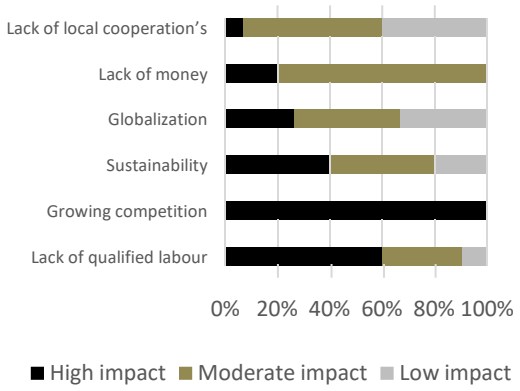

*Fig. 3. Question: What are the biggest challenges concerning your factory?**

The customer requirements concerning the products to be manufactured, growing product complexity and product variance affect companies' business most. In addition to these, shorter product lifecycles and delivery times have a significant impact as well (Fig. 4.).

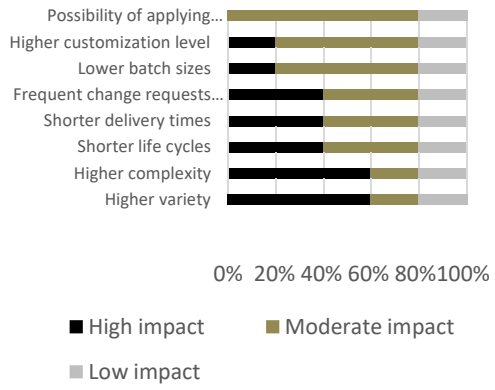

*Fig. 4. Question: Which of the following customer requirements concerning the product affects your company?**

As it can be seen in Fig. 5., R&D, IT, Production, and Logistics will have to fight the most with the new production requirements, whereas sales and purchasing are considered to be less affected.

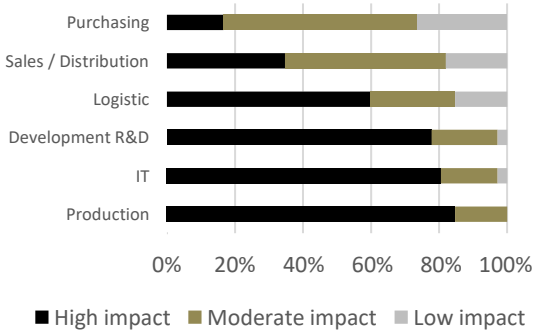

*Fig. 5. Question: What are the areas within your company that will be impacted by your requirements mentioned above?**

Regarding company initiatives implemented in order to cope with the challenges visualized in Table 2, it is further interesting that the changing requirements have not yet led to finished projects of improved product development. Based on the responses, one can also state that there are two main groups of the respondents: one who are not even planning to invest in robots (42%) and the others who have already completed implementing them (33%). In contrast, nearly every company considers education and qualification shortages. The vast majority has already started or completed projects in that domain (71% + 18%). Consequently, it is interesting to see that the respondents have a human-centered approach in manufacturing: a much higher proportion of them is investing in education than robots.

In order to deal with the arising challenges in manufacturing, it is interesting to see that none of the participants has completed the implementation of an Artificial Intelligence (AI) or Big Data solution. Nonetheless, more than two-thirds do state the ongoing implementation of AI.

Table 2. *Question: Do you have implemented initiatives in order to cope with the challenges mentioned above?*

Aspect	No	Planned	In Progress	Completed
Digitization / Automation	22%	0%	64%	14%
AI / Big Data	15%	15%	69%	0%
Robotics / Human Robot Collaboration	42%	11%	14%	33%
New production methods	35%	26%	36%	3%
Product development	22%	18%	60%	0%
Human resource education	6%	6%	71%	18%

The survey comprises questions about smart engineering solutions already in use by the companies (Table 3.). The results show that companies are more likely to use AGVs for transportation than drones. Furthermore, exoskeletons are not as widespread nowadays as it was expected a few years ago. The same is true for VR/AR technologies: only 10% of the respondents have completed implementing this type of solution. A surprising result that 44% of the companies are not even planning to use 5G. The reasons for this are not clear and have to be further explored to go behind these negative figures.

Table 3. *Question: To what extent are the following smart solutions are already in use in your production?*

	No	Planned	In Progress	Completed
Wearables (Smartphone, Glasses, etc.)	43%	7%	31%	19%
Exo-Skeleton	78%	17%	6%	0%
AGVs	31%	21%	11%	38%
Drones	82%	18%	0%	0%
Smart Warehousing	35%	21%	38%	7%
3D-Print	36%	11%	14%	39%
VR / AR	46%	28%	17%	10%
Collaborative Robotics	51%	10%	6%	33%
5G	44%	44%	11%	0%
Public Cloud Services	19%	38%	29%	14%

These two tables show that many of the respondent organizations face the severe problem of the so-called *pilot purgatory* [20].

As shown in Fig. 6., almost half of the companies think that outsourcing their production processes is likely to increase in the future – they probably understand the concepts that have been proposed by researchers in recent years (sharing economy, resource sharing, crowdsourcing, etc.). Surprisingly, more than a third of the respondents think outsourcing of production processes will remain at the same level. Consequently, in some cases, there is a gap between research and industry, even though there are existing solutions for MaaS platforms, such as Xometry (https://www.xometry.com), MFG Custom Manufacturing Marketplace (https://www.mfg.com) or Fictiv Global Manufacturing Network (https://www.fictiv.com).

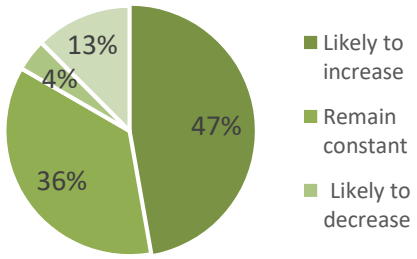

Fig. 6. Question: How will the outsourcing of production processes develop in the future?

More than 70% of the participants think that their business model will likely or very likely shift towards service orientation. This result shows that manufacturing companies could become less hardware-oriented that can affect their entire operation (Fig. 7.).

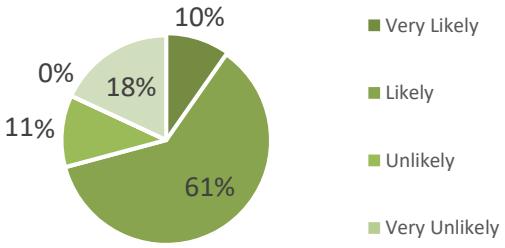

Fig. 7. Question: Do you expect your business model to shift towards a more service-oriented direction?

The survey further assesses the importance of service platforms for companies in their future business. As one can see in Fig. 8., less than 20% of them state high impacts to infrastructure and factory services in future applications. This finding is in sharp contrast to the survey results on IT-based software-defined service solutions, as well as the importance of service platform environments. It has to be discussed why the investigated companies deprioritize the potential fields of manufacturing as a service (MaaS). Meanwhile, they consider further outsourcing of manufacturing processes.

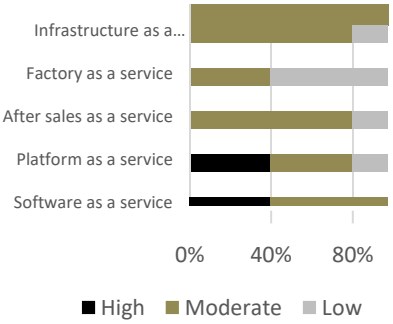

*Fig. 8. Question: How important will service platforms be for your company in the future?**

V. CONCLUSIONS AND OUTLOOK

In this paper, a specific questionnaire-based approach was outlined to demonstrate the far-reaching impacts of digitization on production. Most companies feel the challenges of the new industrial era. However, it is evident from the answers received that apart from the few forerunners, most actors affected have not yet realized the compelling need to speed up adapting themselves to the new business environment and escape the technological pilot purgatory. This is the area they desperately need well-focused assistance.

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REFERENCES

[1] **Westkämper, E.; Löffler, C.**: *Strategien der Produktion*; Book of Springer Berlin Heidelberg, 2016.isbn: 978-3-662-48913-0.doi:10.1007/978-3-662-48914-7.

[2] **Abele, E; Reinhart; G.**: *Zukunft der Produktion: Herausforderungen, Forschungsfelder, Chancen*. s.l.: Carl Hanser Fachbuchverlag, 2011.isbn: 978-3-446-42595-8.doi:10 . 3139 /9783446428058.url:http://www.hanser-elibrary.com/action/show-Book?doi=10.3139/9783446428058.

[3] **Möller. N.**: Bestimmung der Wirtschaftlichkeit wandlungsfähiger Produktionssysteme: Zugl.: *München, Techn. Univ., Diss.*, 2008.Vol. 212. Forschungsberichte IWB. München: Utz, 2008.isbn: 978-3-831-60778-5.

[4] **Nyhuis, P.**: ed. *Wandlungsfähige Produktionssysteme. Schriftenreiheder Hochschulgruppe f ü r Arbeits- und Betriebsorganisation* e.V. (HAB).Berlin: GITO-Verl., 2010.isbn: 9783942183154.

[5] **Koren, Y.**: The global manufacturing revolution: Product-process-business integration and reconfigurable systems. *Wiley series in systems engineering and management.* Hoboken, N.J: Wiley, 2010.isbn: 978-0-470-58377-7.doi:10.1002/9780470618813.url:http://site.ebrary.com/lib/academiccompletetitles/home.action.

[6] **Booth, R.**: . "Agile manufacturing". In: *Engineering Management Journal*, Vol 6.2 (1996), p. 105. ISSN: 09607919.doi:10.1049/em:19960206.

[7] **Fechter M., Foith-Förster, P.; Pfeiffer, M. S.; Bauernhansl, T.**: Axiomatic Design Approach for Human-robot Collaboration in Flexibly Linked Assembly Layouts, *Procedia CIRP* Vol 50 (2016), pp. 629–634.issn: 22128271.doi:10 . 1016 / j .procir.2016.04.186.

[8] **Jain, A., Chan, Jain, P. K., Chan, F. T. S.; Singh, S.**: A review on manufacturing flexibility, *International Journal of Production Research,* Vol. 51.19 (2013), pp. 5946– 5970. ISSN: 0020-7543.doi:10.1080/00207543.2013.824627.

[9] **Hong, P.; Park, Y. W.**: eds. *Rising Asia and American hegemony: Case of competitive firms from four leading nations*. Singapore: Springer, 2019. ISBN: 978-981-13-7634-4.doi:10.1007/978- 981-13-7635-1.

[10] **Mitrakis, N.**: Die Ausrichtung des IT-Service-Managements auf die Digitalisierung. Wiesbaden: *Springer Fachmedien*, Wiesbaden, 2019. ISBN: 9783658253806.doi:10.1007/978-3-658-25380-6. http://dx.doi.org/10.1007/978-3-658-25380-6.

[11] **Küpper, D.; Sieben, Ch.; Kuhlmann, K.; Ahmad, J.; Lim, Y. H.**: Will Flexible-Cell Manufacturing Revolutionize Carmaking?, *Ed. by Boston Consulting Group.* 2018.url:https://www.bcg.com/de-de/publications/2018/flexible-cell-manufacturing-revolutionize-carmaking.aspx.

[12] **Hofmann, C.; Brakemeier, N.; Krahe, C.; Stricker, N.; Lansa, G.**: The Impact of Routing and Operation Flexibility on the Performance of Matrix Production Compared to a Production Line, *Advances in Production Research*. Ed. by Robert Schmitt and Günther Schuh. Vol. 2. Cham: Springer I.P.,2019, pp. 155–165.isbn: 978-3-030-03450-4.doi:10.1007/978-3-030-03451-116.

[13] **Greschke, P.**: Matrix-Produktion als Konzept einer taktunabhängigen Fließfertigung, *Dissertation. Technische Universitä Braunschweig*, 2016.

[14] **Greschke, P.; Schönemann, M.; Thiede, S.; Herrmann, C.**: Matrix Structures for High Volumes and Flexibility in Production Systems, *Procedia CIRP*, Vol17, 2014, pp. 160–165. issn:22128271.doi:10.1016/j.procir.2014.02.040.

[15] **Schönemann, M.; Herrmann, C.; Greschke, P.; Thiede, S.**: Simulation of matrix-structured manufacturing systems, *Journal of Manufacturing Systems*, Vol 37., 2015, pp. 104–112. issn: 02786125, doi:10.1016/j.jmsy.2015.09.002.

[16] **Foith-Förster, P.; Eising, J-H.; Bauernhansl, T.**: Effiziente Montagesysteme ohne Band und Takt: Sind modulare Produktionsstrukturen eine konkurrenzfähige Alternative zur abgetakteten Linie?, *wt Werkstattstechnik online*, 2017. Vol. 107 No. 3, 2017, pp. 169–175.

[17] **Bauernhansl, T.:** Das Fließband läuft aus: Ende eines Paradigmas, *Automationspraxis*, Vol. 5., 2017., pp. 22–23.

[18] **Matt, D. T.**: Achieving Operational Excellence Through Systematic Complexity Reduction in Manufacturing System Design, *Key Engineering Materials,* Vol. 344., 2007., pp. 865–872. issn: 1662-9795. doi:10.4028/www.scientific.net/KEM.344.865.

[19] **Lohse, N.; Hirani, H.; Ratchev, S.**: Equipment ontology for modular reconfigurable assembly systems, *International Journal of Flexible Manufacturing Systems*, Vol. 17.4., 2005., pp. 301–314. issn: 0920-6299. doi:10.1007/s10696-006-9030-0.

[20] **World Economic Forum – McKinsey Company**: Beacons of Technology and Innovation in Manufacturing, Geneva, 2019