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First Results of a Survey on Manufacturing of the Future

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Abstract

Today's production methods are challenged by changing paradigms from a static constraint mass production and mass customization to continuing personalization and regionalization of product, 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 this paper, 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. During this survey, stakeholders and peers from more than 70 companies and research institutions in Germany, Austria and Hungary 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 important topics of future production systems and lessons learned during the evaluation of the survey.

Keywords: Manufacturing Challenges; Future Production Systems; Industrial Survey

1. Introduction

The world is at constant change and we are exposed to disruptions, which can occur suddenly and unexpectedly. The advancing globalization, especially in the manufacturing industry, and the resulting globally connected manufacturing networks lead to fragile production structures which react sensitively to any of those - even slight - disruptions. The ruptures brought in by the economic crisis in 2008 or the contemporary economic restrictions due to CoViD-19 are just some examples that have brought the economic cycle into massive turbulence. The consequences we will have to bear for a long time.

These single events are accompanied and fortified by ongoing trends like the growing world population, an age-

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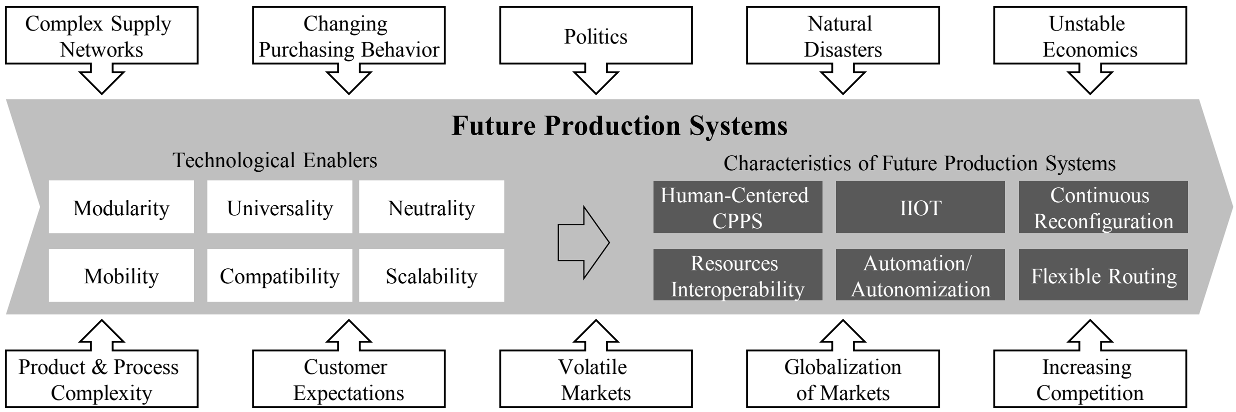


Figure 1: Challenges, Enablers and Characteristics within Future Production Systems

ing society, urbanization and the need for more sustainability [**Moller.2008**, **Abele.2011**, **Westkamper.2016**]. At the same time, companies have to meet increasing customer needs [**Nyhuis.2010**], as they claim more and more individual and personalized products[**Koren.2010**] at lower prices in less time [**Booth.1996**]. Manufacturing companies need to be able to react to these challenges in order to stay competitive and remain a durable business. It requires huge efforts for manufacturing companies to adapt their current production systems and business models according to customers' changing needs [**Mitrakis.2019**]. Today's businesses face various challenges regarding operation and constant reconfiguration. Nyhuis [**Nyhuis.2010**] identified six technological enablers to meet the occurring demands in manufacturing. These are highlighted in Figure 1 alongside the challenges and goals of future production systems.

The consequences of increasingly volatile and fluctuating markets raise the need for adaptable production systems [**Booth.1996**, **Koren.2010**, **Westkamper.2016**, **Fechter.2016**]. Due to the technical limitations of traditional production systems such as Dedicated Manufacturing Lines (DML), the flexibility required to cope with the volatile environments cannot be achieved. New production systems like the Reconfigurable Manufacturing Systems (RMS) or the Matrix-Structured Manufacturing Systems (MMS) are approaches to encounter theses circumstances [**Koren.2010**, **Greschke.2016**, **Greschke.2014**, **Schonemann.2015**, **FoithForster.2017**, **Bauernhansl.2017b**, **Kupper.2018**, **Hofmann.2019**, **Bauernhansl.2020**]. Simulation has shown that the performance of MMS exceeds conventional production methods, especially for high product variance and low production volumes per product [**Greschke.2014**, **Schonemann.2015**, **FoithForster.2017**, **Kupper.2018**].

For manufacturing companies it is not clear so far, what the most promising production system for future use will be and how they can prepare for uncertain future developments coping with limited financial resources.

On the one hand, new production technologies, especially cyber-physical production systems (CPPS) [**Monostori.2016**] provide more flexibility and adaptability in resource utilization, faster ramp-up cycles and a higher range of products to be manufactured. All these measures allow companies to meet customers' demands on a very high functional level.

On the other hand, the uncertainty of future trends and market developments imposes a certain risk on the implementation of these - in most cases - more expensive and complex technologies. In analogy to trading options in financial services, the investment into flexible or changeable production equipment can be compared to an insurance model, whereas the insurance fee is represented by larger debt of service costs due to more expensive equipment [**Bauernhansl.2012**].

Meanwhile, researchers debate on the best production setup in a factory lab environment or simulation. However, requirements in the manufacturing industry may be less sophisticated.

Based on this survey, companies' feedback on current production research development is gained to double-check existing assumptions and defined constraints as well as to validate ongoing efforts and trends in production research. It is intended to evaluate the actual challenges, goals and options thoroughly in order to ensure future success in produc-

tion methodology and technology development. Within this paper, first results from a comprehensive questionnaire on »The intelligent production of the future« performed by a consortium of researchers from SZTAKI and Fraunhofer IPA are presented.
Stakeholders and peers from 72 companies and research institutions all over Austria, Hungary and Germany have been asked to share their impressions, describe their opinions and rate central statements concerning future production systems, methodologies and trends.

The respondents are mainly from the manufacturing industry (83%), 74% of them are typical Small and Medium Enterprise's SMEs, which are usually in the center of national and international funding schemes for production research and, therefore, of special interests for the participating research institutes. Half of them (49%) is engaged in small to medium-sized production of fewer than 100.000 pieces per production order.

2. Motivation and survey structure

The survey »The intelligent production of the future« is composed of 24 individual questions divided into four parts. The structure of the survey and the goals of each single part are highlighted in Table 1. The questionnaire directly asks for and assesses manufacturing companies' opinions and impressions via a web-interface survey template.

Table 1: Survey main parts and objectives

Part	Objectives	Questions
I	general information	1-5
II	future challenges and trends	6-14
III	flexible production systems	15-22
IV	feedback	23-24

The questionnaire was designed in a full standardized form with a pre-defined sequence of 22 closed questions and given responses and 2 open questions about the assessed company itself. Using the network of both research partners, more than 2000 industrial peers were asked to feedback their current situation of implementation and their track of ongoing or finished projects into the area of flexible production systems (FPS).
The paper presents the preliminary evaluation of the received data sets, the corresponding ranking of topics and serves as an industrial point-of-view on current research topics in production system design.

2.1. PART I - General information

PART I aims at collecting basic information about the organization and participant. At this point, important data about the geographical location, business branch and main mode of production operation are gathered. These data sets are used to distinguish the organizations in later evaluation steps.

2.2. PART II - Future challenges and trends

PART II tries to understand the biggest threats and requirements the companies have to face at the moment and how they define their measures to encounter this change. This particularly concerns their current mode of operation and their initiatives to cope with the challenges in manufacturing.

The results of PART II are part of a current analysis and will be presented in another paper.

2.3. PART III - Flexible production systems

The questions and responses within PART III represent the core of this paper. The main idea is to assess industrial feedback on potentially new production technologies and systems considering their ability to solve the current chal-

lenges in production system design.
In detail, the questions focus on enabling technologies for flexibility in production, such as:

(i) modular production equipment and cells
(ii) routing flexibility between production cells
(iii) communication architectures in production
(iv) reconfiguration of production layouts

Furthermore, each of the enabling technologies is investigated in which way it might improve corresponding production KPIs, such as:

(i) resource utilization
(ii) space consumption
(iii) scalability of production volume
(iv) integration of new product variants
(v) reduction of lead times
(vi) product variant diversity

2.4. PART IV - Feedback

The last part raises contact details about the organization and the participant, in particular to distribute the results.

3. Method

The results presented in this paper are the statistical analysis of the responses from a company survey in which over 2000 industrial contacts were questioned. There are a total of 72 usable, fully completed questionnaires (response rate <3.5%). In the course of the Preliminary Results, no statistical correlations between the answers have yet been examined. In the industrial sector surveyed there are around 30,000 companies in Germany, Hungary and Austria. With a confidence interval of 95% and an error margin of 10%, the required sample of responses for statistical relevance can be calculated to 68. With a total of 72 complete responses, the statistical relevance of this survey is given.

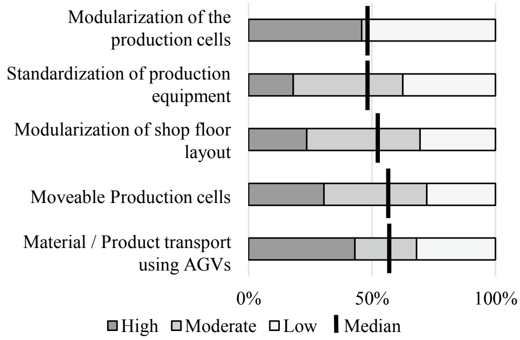
4. Results

This paper focuses on the results gained during the analysis of the answers given for PART III. Companies that participated in the survey are almost equally distributed between Research & Development and Manufacturing.

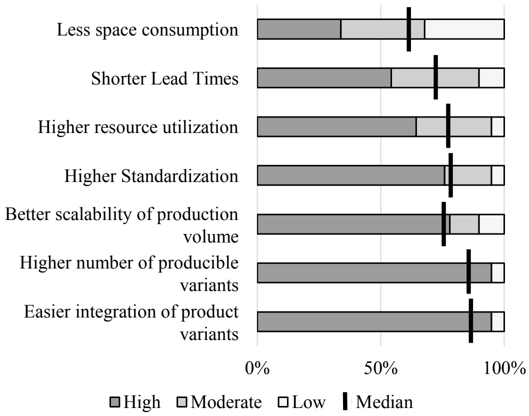
Since PART III focuses on flexible production systems, it was desired to get qualitative feedback on the companies' impressions on current tracks of production research. The respondents were asked to provide a rating with a relative score between [1..10] ranging from very low to very high. For this evaluation, answers in the interval [1..3] are considered »low«, [4..7] as »moderate« and [7..10] »high«. The characteristic of scale (»importance«, »impact« or »benefit«) is dependent on the question type and objective. The following figures were sorted according to the median score.

The evaluation of PART III starts with QUESTION 15. It is interesting to see that less than 20% of the companies think that standardization of production equipment will provide high potential for flexibility in production. Autonomous material and product transport in production using Automated Guided Vehicle's AGVs (43%) and the modularization of production layout (46%) for easier reconfiguration are considered more promising. Interestingly, the responses on modularization of production equipment are quite ambiguous, since about the same amount of assessed companies (51%) state a low impact on the flexibility. The remaining technologies receive medium scores, e.g. the modularization of shop-floor layouts and mobile production cells.

The results on QUESTION 17 show that companies understand the benefits of modular production cells. Being asked if the use of modular production cells would be beneficial for their production processes, 75% of the respon-



QUESTION 15: How would you evaluate the following technologies regarding their potential towards flexibility?



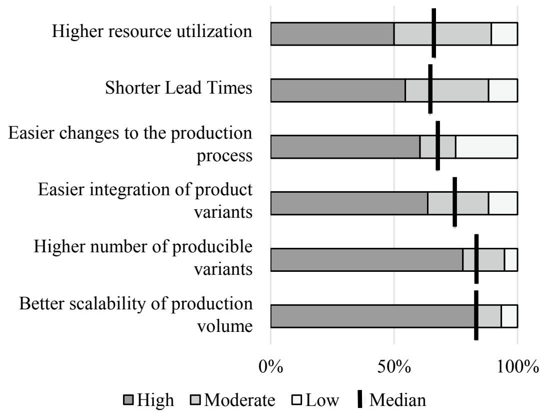
QUESTION 17: How can modular production cells help your production process?

dents affirm. 95% of them think it can be profitable because the integration of new and different product variants might be easier, and the potential number of variants might be higher. They also expect better scalability and higher standardization of resource equipment. However, the results on space consumption also show that companies are not yet convinced or have doubts about space requirements in modular production.

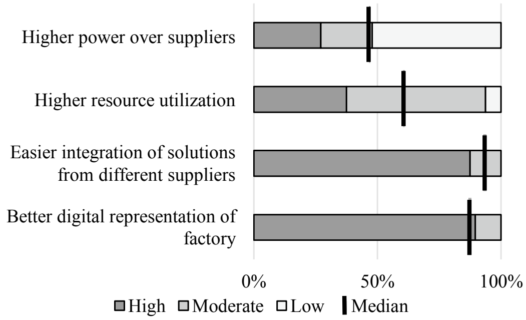
QUESTION 18 shows, that around 80% of the companies are confident that the gained flexibility through variable linking of production cells will deliver a better scalability of the production volume and a higher number of variants. There are still doubts about resource utilization and achievement of potentially shorter lead times. In total, the majority of companies expect medium to high benefits concerning modular production systems. None of the mentioned criteria were devaluated, and the overall consent prevails.

Around two-thirds of the participants consider a flexible communication architecture within production to be beneficial to their business. As shown in QUESTION 20, about 50% of the companies do not specifically consider using the communication architecture to obtain higher power over their supplier network. Almost 90% expect the communication will benefit in easier integration of manufacturing solutions from different suppliers and better digital representation of the factory.

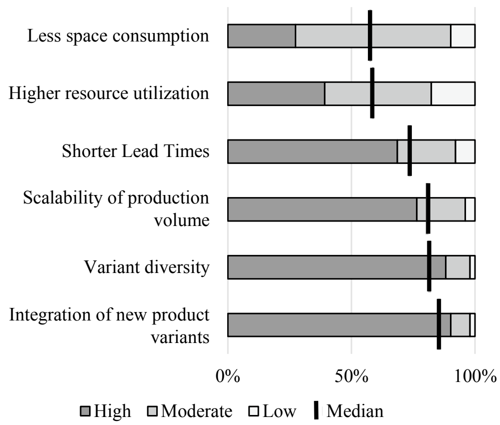
The last question addresses the topic of continuous autonomous reconfiguration of the production layout, see QUESTION 22. Being asked if this would benefit their business, about 70% of the interviewed companies affirm. Companies suppose the reconfiguration especially supports the integration of new product variants and increasing variant diversity. Positive impacts are expected for the implementation of shorter lead times and an easier scalability



QUESTION 18: How can the flexible linking of production cells benefit the production process?



QUESTION 20: How can a flexible communication architecture within production help you?



QUESTION 22: How can the continuous, autonomous reconfiguration of the production layout help you?

of production volume.

The detailed responses per individual goal of Questions 17-22 was to be investigated and compared in detail. Therefore, the individual results per goal are cross-evaluated and ranked to get a deeper understanding of the main

Table 2: Cross-check evaluation of technologies and intended benefit

	modular production cells	flexible linking of production cells	autonomous reconfiguration of production layout
higher resource utilization	●	◑	○
better scalability of production volume	◑	●	○
easier integration of product variants	●	○	◑
higher product portfolio	●	○	◑
shorter lead times	○	◑	●

Legend: ●: well suited, ◑: partly suited, ○: not suited

performance drivers and enabling technologies for modular production. Table 2 describes the five main characteristics of modular production systems, the respondents evaluated. Comparing the responses given on the benefits of modular production cells, flexible linking of production cells and continuous, autonomous reconfiguration of the production layout, the following conclusions can be drawn. Table 2 shows the comparison between the mentioned production methods using Harvey balls.

5. Conclusions

Overall, about 75% consider reconfigurable production systems beneficial for their operation. For 50% of the participants modular production cells and the material transport with AGVs are promising. The combination of both technologies promises an easier integration of new product variants, a higher number of producible product variants and better scalability of production volume.
Around 65% state that the flexible linkage of production cells might be beneficial for various reasons. In particular through the easier integration of high variant numbers.
Having modular production cells from various equipment suppliers running within the same constantly configuring factory, requires flexible communication architectures. Therefore, 70% of the respondents state that having a flexible communication architecture is mandatory for successfully implementing future production systems.

6. Lessons Learned & Outlook

In the following, the identified requirements for future production systems derived from Tab. 2 are summarized:

(i) Modular production cells consisting of cyber-physical production systems (CPPS) support the easier integration of new product variants and a larger product portfolio as well as a higher resource utilization.

(ii) The flexible linking of production cells and the inherent routing flexibility allows for dynamic, on demand adaptions of material flow. Thus allowing for better resource utilization and easier scalability of production volume.

(iii) Autonomous reconfiguration of production cells and their position on the shop floor layout shortens the reaction times required to adapt to different production scenarios and, therefore, allows for short lead times and optimal operation points.

The responses show a large overlap between research intentions and highlight confidence in current production research. The results of this survey and the conclusions drawn within this paper will be part of ongoing research at the ARENA2036 research campus and EPIC project center, where Future Production Systems like Matrix Manufacturing System (MMS) or Fluid Production Systems (FPS) are developed.

To get a deeper understanding of the constantly evolving challenges impacting manufacturing companies, and to identify the business units which are most affected, the survey results of PART II are comprehensively evaluated and will be published in a separate research paper.

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