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Status Quo on Production Planning and Control

Tabea Marie Demke[1], Tobias Hiller[1], Kira Welzel[1], Constantin Steffens[2], Christopher Mundt[2], Volodymyr Alieksieiev[2], Judith Fulterer[3], Jan Maetschke[3], Calvin Kuhn[3], Vincent Kalchschmid[4], Mario Luber[4]

[1]Institute of Production Systems and Logistics/ Leibniz University Hannover, 30823 Garbsen, Germany
[2]*Institute of Production Management and Technology/ Hamburg University of Technology, Hamburg, Germany*
[3]*Laboratory for Machine Tools and Production Engineering (WZL)/ RWTH Aachen University, Aachen, Germany*
[4]*Fraunhofer Institute for Casting, Composite and Processing Technology IGCV, Augsburg, Germany*

Abstract

What is the status quo in production planning and control (PPC)? This question is the recurring basis for the *PPS Report*, which has now been initiated for the sixth time by the following four German institutes in the field of production technology: Institute of Production Systems and Logistics (IFA) at Leibniz Universität Hannover, Institute of Production Management and Technology (IPMT) at Hamburg University of Technology, Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University and Fraunhofer Institute for Casting, Composite and Processing Technology (IGCV). The aim of this survey is to regularly establish a picture of current approaches and challenges companies face in relation to PPC. The current report focuses on the areas of data collection, logistic objectives and sustainability in PPC. The results of the report show the approaches and challenges of the companies surveyed in achieving logistic objectives, such as schedule reliability, and in digitization, especially with regard to collecting and using data from production processes. Furthermore, the report highlights the challenges that prevent companies from implementing a circular economy, namely high complexity and uncertainty. Additionally, the report addresses how companies deal with high and volatile energy prices, which most of the companies surveyed have not yet taken into account in their PPC.

Keywords

Production Planning and Control; Survey; Sustainability; Data Collection; System of Objectives; Circular Economy; Energy

1. Introduction

In addition to product quality and product costs, the logistic performance of manufacturing companies has become increasingly important as a strategic competitive factor in recent decades [1,2]. Manufacturing companies with an outstanding logistic performance grow faster and have higher profits. As a result, companies also focus on a high delivery reliability and short delivery times to remain competitive [3]. In addition, environmental regulations and problems such as climate change, raw material depletion and other external factors are increasing the pressure on manufacturing companies to improve not only their logistic performance, but also their ecological performance [4]. One strategy that companies can employ to enhance their ecological performance is to implement circular economic practices [5]. In some cases, there are even overlaps between these objectives. An increased use of renewable energies or the direct processing of production waste, for example, can reduce both production costs and environmental impact. However, this

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approach may also result in fluctuations in energy prices [6]. In other cases, logistic and ecological objectives have the opposite effect. For example, service-level driven make-to-stock production runs the risk of holding excess materials, resulting in unnecessary waste of resources.

These developments require companies to (1) improve their logistic performance to remain competitive, (2) understand and apply new business models such as circular economy, and (3) react to the increasingly volatile situation in energy markets due to the growing share of renewable energies. These requirements for manufacturing companies are subsequently considered as key challenges. The task of PPC is to realize order processing logistically efficient, starting with the planning of the production program, resources and materials through to the implementation of the production program despite unexpected disruptions [7]. By planning and controlling order throughput, PPC plays a central role in overcoming the challenges outlined above.

The four production technology research institutes Institute of Production Systems and Logistics (IFA) at Leibniz Universität Hannover, Institute of Production Management and Technology (IPMT) at Hamburg University of Technology, Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University and Fraunhofer Institute for Casting, Composite and Processing Technology (IGCV) have joined to regularly record the status quo of PPC in a study to create transparency about current trends and challenges in the context of PPC. The survey for year 2023 is already the sixth joint study[1] and now looks at the current status of PPC with regard to the key challenges *(1) Data collection and systems of objectives, (2) circular economy and (3) energy* (see [13] for the original study). The three topics addressed in the study result from the aforementioned and currently existing key challenges for manufacturing companies. Therefore, the key challenges represent the subsections of Section 3 “Study Results”. Section 3.1 provides results of the study conducted to improve logistic performance to remain competitive based on an adequate Data collection as well as under consideration of logistic cause-effect relationships within systems of objectives (see key challenge (1)). Section 3.2 contains results not only in terms of strategies and measures for implementing circular economy but also associated challenges (see key challenge (2)). Section 3.3 represents challenges and measures including metrics to sensitize and enable manufacturing companies to deal with volatile energy markets with regard to energy-oriented metrics, industrial energy generation and energy self-sufficiency (see key challenge (3)). Finally, this article summarizes the most important findings of the study conducted, identifies current industry trends for researchers and provides a benchmark for practitioners in manufacturing companies to support the adequate addressing of the aforementioned key challenges.

2. Survey Respondents

The survey was conducted via an online questionnaire between Q1/2023 and Q3/2023. A total of 47 analyzable questionnaires were collected. Respondents represent German manufacturing companies and a wide range of industries, with the majority (44 %) from machinery and plant engineering sector. With regard to the type of order fulfilment, a broad picture emerges, with a majority of 33 % in the engineer-to-order segment (see Figure 1).

[1] Former studies had the following topics: *Use of feedback data* [8], *Challenges in PPS* [[9]], *Processes used in PPS* [[10]], *Digital Transformation* [[11]] and *Robustness, sustainability and complexity management* [[12]]

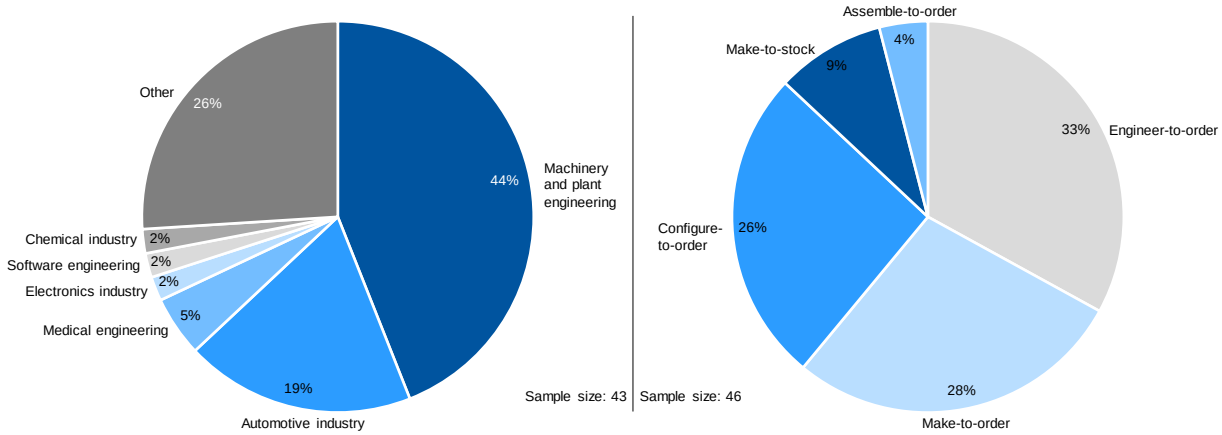

Figure 1: Results of the question as to which type of order fulfilment forms the focus of production of the participants surveyed (left) and affiliation to industrial sector (right)

66 % of the companies surveyed have more than 1,000 employees. The report therefore rather reflects the perspective of larger companies. Furthermore, 40 % of the companies polled have a revenue of more than 500 million Euros. Respondents have production sites worldwide, with 87 % producing in Germany, 60 % in other European countries, 49 % in Asia and 40 % in North America. The main type of production is individual and small series production (48 %) and large series production (22 %). Only 15 % describe their type of production as mass production.

3. Study Results

According to the topics of the report, the questionnaire is divided into three parts: data collection and systems of objectives (see Section 3.1), circular economy (see Section 3.2) and energy (see Section 3.3).

3.1 Systems of Objectives and Data Collection

In make-to-order production, achieving a high delivery compliance is of strategic importance for the company's success, as meeting promised delivery dates supports a trust-based relationship with customers and avoids expensive follow-up costs [14,15,3,16,17]. The results of the survey show that around one third of companies achieve a delivery compliance of 75 % or less. There are many reasons why delivery times are not met: the most frequently cited reason is the availability of materials. Other reasons include the handling of rush orders, capacity bottlenecks, staff shortages and backlogs. The companies surveyed are primarily attempting to increase delivery compliance by improving the planning processes and reducing backlogs. In this survey, sequencing discipline is underrepresented as a negative influence or improvement potential for the delivery compliance. There may be two reasons for this: either there is a high level of sequencing discipline in companies or there is a lack of awareness of the negative effects on meeting delivery compliance. The *PPS Report* from 2016 [9] already confirmed that 30 % of companies consider sequencing to be of minor importance and only 23 % of the companies use earliest operation due date (EODD) sequencing. For some make-to-order production companies, achieving high delivery compliance seems to be a challenge. The survey revealed various needs for make-to-order companies to improve PPC. Firstly, companies need simple and comprehensible models, for example to understand the negative consequences of order sequence deviations for lateness. Secondly, they need simple and practicable procedures to deal with uncertainties and still generate an effective and stable PPC.

In make-to-stock production, the service level is one of the most important external logistic objectives, because, on the one hand, a low service level can lead to a loss of sales [18,19,3,20]. On the other hand, excessive finished inventory goods tie up capital and negatively impact the return on investment, as finished inventory is more expensive due to its higher value. 34 of the 47 companies surveyed answered the questions about make-to-stock production. However, only four of the companies stated that they are primarily organized as make-to-stock, indicating that mixed production, in which make-to-order and make-to-stock production coexist, is widespread. Around two thirds of companies with make-to-stock production have a service level of more than 90 % and less than one fifth of those companies have a service level of more than 99 %. The survey also shows that material availability has a negative impact on the service level for around 60 % of responding companies. Around half of the responding companies state that capacity bottlenecks or an unforeseen increase in customer demand negatively impact the service level. The most common approaches to improving the service level are higher safety stock levels and more constant and shorter throughput times. Improving the service level by setting higher safety stock levels comes with the downside of higher capital lockup costs. Reducing and stabilizing throughput times in contrast lowers the required safety stock levels. The results of the survey show that make-to-stock companies have a need for further development of PPC. Firstly, they need simple and comprehensible models to understand negative consequences such as an increase in safety stock. Secondly, companies need simple and practicable procedures to deal with uncertainties such as fluctuating customer demand. Thirdly, supply chain management and PPC should be integrated in order to increase material availability.

Furthermore, the companies were asked about setup times. The majority of the companies surveyed stated that setup times account for a large proportion of the order time. Overall, one third of the companies stated that setup times account for more than 10 % of order times. According to the survey, the main negative influences on setup times are a lack of automation solutions and a shortage of equipment. Other less common reasons are a lack of proper documentation and training to set up machines efficiently. Around one third of the companies do not take any measures to reduce setup efforts. This is also true for the companies with a set up times greater 10 %. This indicates that either these companies consider setup time to be of low relevance or underestimate the importance of setups times. Around half of the companies stated in the survey that they reduce setup times using methods such as Single Minute Exchange of Die (SMED) or setup-optimized sequencing [21]. Set-up times cause considerable effort in the production of many companies and therefore also offer considerable potential for improvement. Companies should actively address the impact of set-up processes. Also in this regard, feasible models and procedures can support companies.

Shop floor data is essential to measure objectives and to gain transparency over and insights into the production system in order to improve its performance [22,23]. E.g., a crucial challenge for an effective PPC is to accurately predict resource parameters [24,25], e.g. process times and technical availability. The respondents of the study see the improvement of planning data as the main factor to improve their on-time delivery rate. This can be achieved through the analysis of shop floor data [26]. In the context of the Industrial Internet of Things, the usage of sensor technology and connectivity of productions resources is increasing. This enables the collection of detailed and accurate data from production resources such as machines and other work centers [27,28]. Three quarters of the respondents of the survey use resource data collection to acquire feedback data like process times and yield quantities. Additionally, half of the respondents employ resource data collection to react to events such as disruptions. Less than a third of the respondents utilize resource data collection in the context of PPC for more advanced insights based on data analysis and for the prediction of resource parameters. The respondents of the study expect an increase in efficiency and quality of the production system from expanding the collection and usage of shop floor data. But the technical complexity and the lack of human resources are named as obstacles to exploit more benefits (see Figure 2). That goes in hand with the fact that the respondents are predominantly considering to develop company-specific solutions and to build up skills and staff in information technology in order to expand the collection

and usage of shop floor data. Already previous iterations of this study [11,10,12] had shown that while the analysis of shop floor data is considered useful, it is predominantly analyzed manually with a high effort, and the deployed information technology is not advanced and not sufficient.

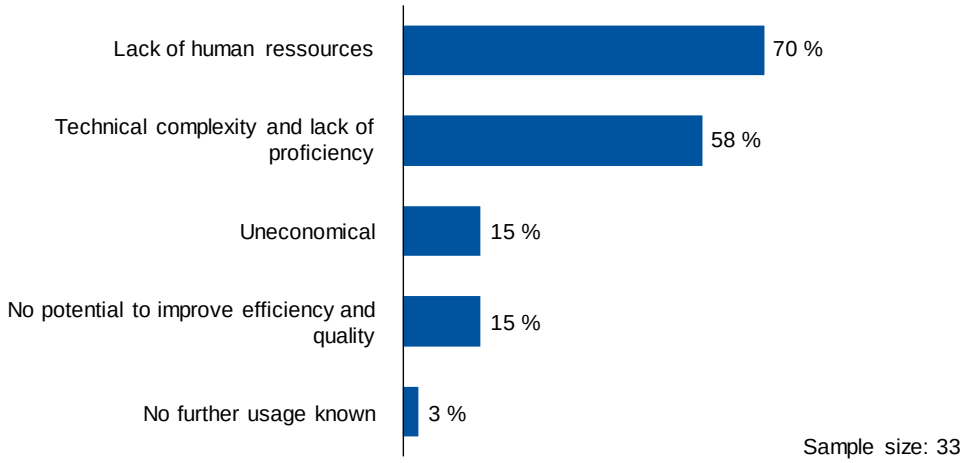

Figure 2: Survey responses on why data collection and usage in production is not expanded

Standardized, ideally automated solutions constitute an approach to reduce the complexity and manual effort of the data analysis process in the context of PPC [29,30]. Less than a quarter of the respondents referenced existing standardized solutions to expand the usage of shop floor data. That indicates a lack of such solutions for the data analysis process in PPC, which need to be developed in future work.

Two practical conclusions can be derived from this for companies: Firstly, companies need to raise awareness of the importance of sequencing, especially among production staff, in order to improve their schedule reliability in this regard. Secondly, shop floor data should be collected in a uniform, structured way to enable standardized data analysis solutions.

3.2 Circular Economy

This year's report highlights sustainability within the context of PPC in German manufacturing companies, an puts a special emphasis on the challenges in adopting circular economy. These challenges mainly occur due to uncertainties in the quality, quantity and timing of the old products [31]. The uncertainties lead to changes in the tasks of the linear PPC as well as adding new tasks for managing the product return [32]. The survey suggests, that while some strategies for circular production have already been implemented, further potential exists to expand the scope and depth of circular economy activities. Activities in production related to circularity mentioned by the companies surveyed are repair (37 %) as the most common activity, followed by recycling (27 %) and refurbishment (21 %). The most significant challenges in adopting circular economy are reported to be technical feasibility (24 %), regulations (21 %) and production planning (18 %).

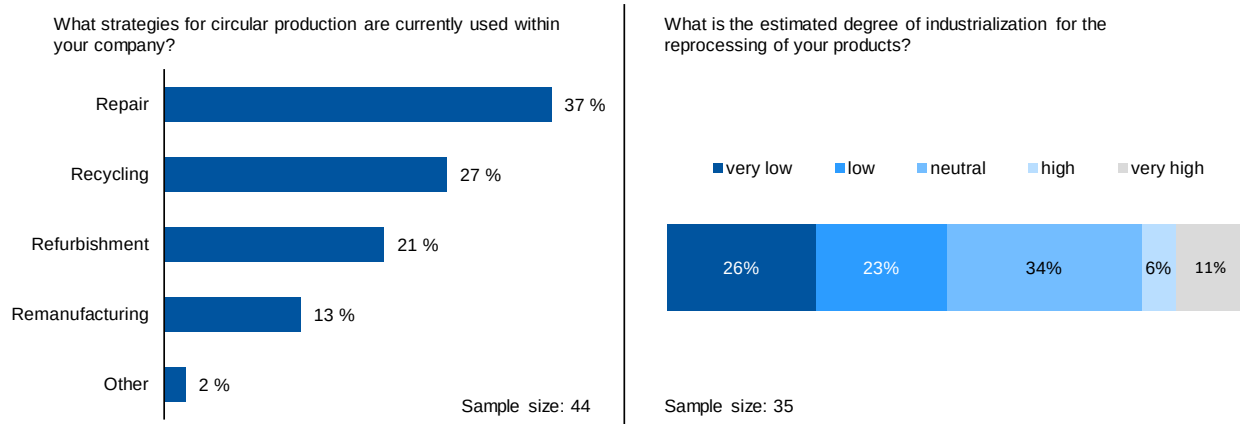

Figure 3: Survey results for the reported strategies currently employed within circular production as well as the degree of industrialization for the reprocessing of products

In the context of planning measures to further promote circular economy, 27 % of the companies reported to focus on research and development on measures to enable circular economy. Planning and control (21 %) and manufacturing, as well as production technologies (21 %) and sales (19 %) are also mentioned as areas for the implementation of measures regarding the promotion of circular economy. In contrast, only 10 % of respondents reported to plan any measures in the procurement department. The reported focus of existing measures to promote circular economy partly address the challenges to implement circular economy. As such, the challenge of technical feasibility is addressed through measures in production technology and the challenges in production planning are addressed by measures regarding planning and control. In general, the status for the implementation of circular economy in most industries is estimated to be the development of suitable products.

One aim for the development of products suitable for circular production is to enable industrialization of circular production [33]. The survey showed that most companies have potential in the further industrialization of activities for the reprocessing of past products. Merely, 17 % of respondents reported a “high” or “very high” degree of industrialization with 49 % of respondents reporting the degree of industrialization to be “low” or “very low”. The greatest challenges in reprocessing, as identified by the companies, lie within the reprocessing process itself, as reported by 29 % of companies. This is followed by disassembly (21 %) and production planning (18 %). In contrast, none of the participants reported the reassembly process as a challenge.

To overcome these challenges, many companies are investing in product development (46 %) and employee qualification (41 %), in addition to standardization (37 %) of components and processes. Only 2 % of the companies reported measures for the utilization of robotics for reprocessing. In planning reprocessing processes, companies rely on product data (32 %), service history data (25 %), production data (22 %) and user data (18 %). The usage of data is considered to have a high potential for the implementation of circular economy. 39 % of companies reported the data quality to be “high” or “very high”. Most companies reported the data quality to be “neutral” (42 %). While this points at a good general level of data quality, it also hints at potentials for further improvements in most companies. To improve data quality, 41 % of companies are adopting Life Cycle Management technologies and tools. Forecasting algorithms are less common with 23 % of respondents using forecasts of spare parts demands, 20 % deploying predictive maintenance, 10 % utilizing artificial intelligence and only 7 % forecasts of delivery times.

In summary, the report indicates that circular economy exists in some cases but has potential for further improvement in the manufacturing industry. A wide range of reported measures for the adoption of reprocessing strategies indicate an interest and an ongoing process for the implementation of circular economy amongst the respondents. The wider adoption of circular economy would have the potential of

decreasing material costs as well as improving the ecological footprint of producing companies. The current unfulfilled potential for wider adoption, despite ongoing interest, indicates the need for further development for concepts regarding circular economy. In particular, the increase in complexity and uncertainty poses a challenge to production planning procedures, such that further development towards the production planning in circular economy has the potential for assisting in the wider adoption. Practical implications for industry are that further focus on circular economy beyond repair and recycling would have the potential to boost profit margins, as the reuse of components removes the purchasing costs of those components. To enable this, companies should focus on the modular development of products, such that long lasting components can be reprocessed, as well as further industrialization of reprocessing processes.

3.3 Energy

Energy use in factory operation and therefore in industrial production plays a key role in the quest of increasing environmental sustainability in manufacturing [34]. In addition, energy became increasingly prominent from an economic perspective through volatile markets in the past two years. Between 2019 and the second half of 2022, average industrial electricity prices in Germany have increased by approximately 200 % from 17.76 to 53.38 €/MWh. Although prices showed a significant trend of recovery with a decrease back to 24.86 €/MWh in 2023, prices still remain on a high level [35].

Despite this drastic increase and the growing fluctuation of energy availability, showing in the long-term-development of electricity exchange prices [36], the potential in the consideration of energy prices in PPC currently has not been fully recognized by the manufacturing companies surveyed: As shown in Figure 4, 63 % of the survey participants do not consider short-term fluctuations in energy prices in their PPC at all, while 23 % do so to only a small extent. Compared to the *PPS Report* from 2019, the trend has not changed despite the energy crisis, as 81 % of respondents stated that they do not take energy data into account [11]. Looking ahead, 84 % of respondents plan on implementing energy related KPI weighted in their PPC's system of objectives only at very low (52 %) to low (32 %) levels in the future. Energy-oriented PPC (ePPC) adds energy usage to the system of objectives, e. g. through the consideration of energy cost in production cost models [37]. Through this, it allows manufacturing companies to take advantage of fluctuating energy prices deriving from varying energy production of renewable energy sources by adjusting energy-intensive processes to energy availability. As of now, it does not play a significant role. One reason for this might be found in structure of the companies surveyed and their level of energy intensity. For example, only 2 % of the survey participants are from the field of chemical industry, which is one of the main energy users in Germany.

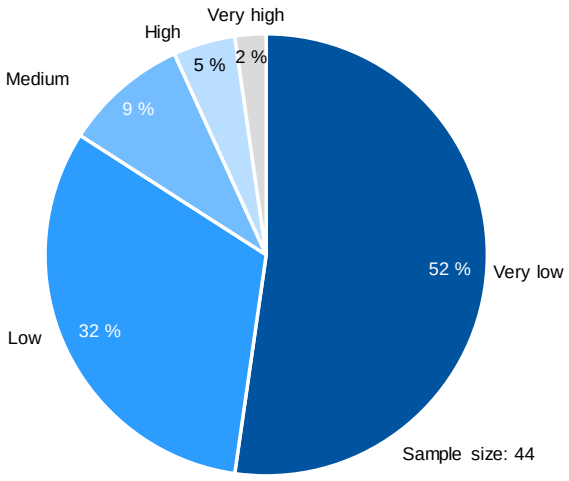

Figure 4: Planned future weighting of energy-related KPIs in PPC target systems of surveyed companies

The main challenges in reacting to short-term fluctuations in energy prices in their production systems faced by the respondents are lack of energy flexibility potential (31 %), of integration of energy flexibility measures into their PPC system (26 %), of access to dynamic electricity prices (26 %), of specialist knowledge (12 %) and of data on fluctuating electricity prices (7 %) while 24 % see no relevance in the topic at all. Overall, motivation for energy-oriented PPC in relation to short-term fluctuating energy prices remains at a low level and is rated as non-relevant for the future while the potential capabilities towards energy flexibility is estimated to be limited by a large amount of the companies surveyed. This leads to the assumption that further transparency in the benefit of ePPC needs to be brought to all sizes and levels of energy intensity of manufacturing companies.

With rising uncertainties of security of energy supply against the background of recent geopolitical developments, incentives for energy own-consumption for manufacturing companies in their role as factory operators are growing [38]. Also, driving industrial energy supply towards an ecologically sustainable future is a key task in the effort to preserve and expand prosperity globally [39]. Sustainable energy supply is gaining more and more importance with rising numbers of companies proclaiming greenhouse gas neutrality goals for themselves and their supply chain while legal requirements are gradually increased [40]. These current developments in markets, sustainability goals, regulations and reporting duties for industrial companies could accelerate the build-up of awareness of the importance and potentials of energy sourcing and flexibility. Green on-site energy generation from wind or solar energy is a main means in this context. According to the survey, energy self-sufficiency or own-consumption of renewable energy is already relevant for the respondents. 42 % rate the topic at medium importance. 26 % assign it a high level of importance and 5 % a very high level of importance while 30 % rate importance at a low (12 %) or very low (16 %) level.

However, more than three quarters of the participants (76 %) do not consider on-site-energy-generation-related constraints and factors in their PPC at all The *PPS Report* from 2019 shows similar results, although more companies are now including energy-related aspects in their PPC [11]. A huge part of the companies surveyed see missing or too small capacities for on-site energy generation and energy storage as a major challenge in the feat of increasing their energy self-consumption. About a quarter name both lack of willingness to invest in the expansion of generation capacities and energy storage systems as well as conflicts between classic logistic objectives variables related to PPC and energy self-sufficiency based on fluctuating renewable energy sources as the main issues. This is also an obstacle for companies faced with the need to adapt to this type of energy supply in their production system due to a lack of energy flexibility.

ePPC can improve companies' economic performance. The questions on energy usage show that the practical implications should (1) encourage companies to develop the expertise to respond to short-term flucations and (2) build on-site energy generation and storage systems. Tackling these challenges, about half of the participating companies plan to invest in on-site energy generation technologies while 19 % look into setting up energy storage systems. This clashes with 31 % of the respondents who do not want to take any action to increase their energy self-sufficiency. In terms of practical implications, this shows that suitable energy concept strategies aiming at on-site own-consumption, specifically tailored to the needs and constraints of manufacturing companies, need to be developed and adopted by companies.

4. Summary and Outlook

47 companies were surveyed on three present key challenges for manufacturing companies.

Key challenge (1) focuses on improving logistic performance through better data collection and an understanding of cause-effect relationships within systems of objectives. The results show, that many companies still have a potential to particularly improve delivery compliance. Improving the availability of materials, processing rush orders, reducing capacity bottlenecks, eliminating staff shortages and reducing

backlogs are key areas of focus here. The importance of the sequencing discipline does not yet seem to be recognized by companies, although it has significant impact on delivery compliance. One third of the companies reporting high setup times do not consider implementing measures to reduce setup times. This indicates that the setup time is considered to be of low relevance or that its importance is underestimated. Economic and functional benefits are also evident in the expansion of shop floor data usage. However, the high technical complexity and the lack of human resources are cited as obstacles, suggesting a lack of standardized, machine-based data analysis solutions for PPC.

Key challenge (2) addresses strategies and hurdles for implementing circular economy practices. A wide range circular economy measures reported by the companies surveyed, mainly related to research and development, indicate an interest in expanding circular production approaches. In particular, reprocessing activities seem to have potential for further industrialization.

Key challenge (3) highlights the need for manufacturing companies to adapt to volatile energy markets by focusing on energy-oriented metrics, industrial energy generation, and energy self-sufficiency. The study results point out that PPC-systems do not integrate the energy flexibility required to meet the short-term fluctuating energy prices. With energy self-sufficiency considered a relevant issue, respondents see expanding on-site energy generation and storage capacity as challenging.

As the contributing research institutes IFA, IPMT, WZL, and IGCV continue to track trends and challenges in PPC within their unique periodic study in Germany, future research work should focus on developing advanced methodologies and tools to enhance data collection systems and align them with manufacturing companies' logistic objectives. Additionally, research institutions can contribute to the industrialization of circular economy practices by providing innovative solutions for overcoming the barriers companies face in implementation. In the area of energy management, further research should aim at creating practical frameworks and metrics that enable manufacturing companies to effectively utilize volatile energy markets, increase energy self-sufficiency, and integrate renewable energy into production processes.

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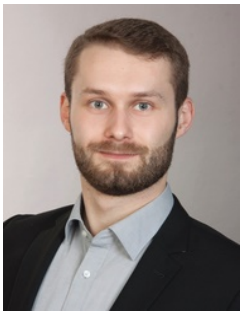
Biography

Tabea Marie Demke (*1993) received her M. Sc. in production and logistics from Leibniz University Hannover. Since 2021, she has been working as a Research Associate at the Institute of Production Systems and Logistics (IFA), Leibniz University Hannover, in the field of production management.

Tobias Hiller (*1990) received the M.Sc. degree in management with focus on production and logistics from Georg August University of Göttingen. Since 2019, he has been working as a Research Associate in the field of production management with the Institute of Production Systems and Logistics (IFA), Leibniz University Hannover.

Kira Welzel (*1998) received her M. Sc. in industrial engineering with focus on mechanical engineering from Technische Universität Braunschweig. Since 2023, she has been working as a Research Associate at the Institute of Production Systems and Logistics (IFA), Leibniz University Hannover, in the field of production management.

Constantin Steffens (*1993) studied Industrial Engineering at the University of Applied Sciences Stralsund and at the Otto von Guericke University Magdeburg. From 2021 to 2022 he was working at the Salzgitter Flachstahl GmbH. Since 2022, he has been working as a research associate at the Institute of Production Management and Technology at Hamburg University of Technology. His research focus is production planning and control.



Christopher Mundt (*1993) studied Mechanical Engineering in Hamburg with a focus on production management and technology. Since 2019, he has been working as a research associate and from 2023 as chief engineer at the Institute of Production Management and Technology at the Hamburg University of Technology.

Volodymyr Alieksieiev (*1999) completed his master's degree in Production and Logistics at Leibniz University Hannover. Since December 2022 he works as a research associate at the Institute of Production Management and Technology. His researches focus on modelling of transhipment processes at intermodal terminals and production planning and control.

Judith Fulterer (*1994) studied industrial engineering and management specializing in mechanical engineering at RWTH Aachen University. She started working at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University in 2018 and heads the Production Logistics Group in the Production Management Department.

Jan Maetschke (*1994) studied mechanical engineering and production technology at RWTH Aachen University. He started working at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University in 2019 and heads the Production Logistics Group in the Production Management Department.

Calvin Kuhn (*1998) studied mechanical engineering at RWTH Aachen University, specializing in production technology and business organization. After graduating with a master's degree in 2022, he joined the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University.

Vincent Kalchschmid (*1996) joined Fraunhofer IGCV a research associate at in 2021 after hie Masters' studies in Energy Technology. Since then, he has been contributing to the institute's studies in the fields of Production Planning and Control, industrial energy supply and sustainable production.

Mario Luber (*1989) studied Mechanical Engineering and Management at the Technical University of Munich. After that he worked for several years as a consultant for production planning solutions in SAP systems. Since 2022 he works as a research assistant at Fraunhofer IGCV. He focuses on the application of digital twin concepts and machine learning in the field of production planning and control.