Room for Improvement? – Current issues in highly automated manufacturing

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Abstract

Background – Companies have to constantly improve and adapt to the dynamically changing conditions, in order to remain competitive. This implies a fundamental change in the organization and the mindset of employees, as well as a continuous improvement of internal processes, in both direct and indirect areas. Especially in a highly automated production, thins leads to a new level of complexity, that adds to the difficulty to further improve existing processes.

Purpose –. This paper gives insights into the discussion of the future role of process improvement in highly automated production and the relevance of new digital technologies to further enhance productivity.

Methodology/Approach – In order to address the research question, virtual focus groups have been chosen as a qualitative approach. Seven executives of German large-scale enterprises assessed the future role of process improvements in a highly automated manufacturing setting.

Findings – Results show that the potential for process improvements in manufacturing is still high. While the integration of continuous process improvement aims for incremental improvements, new technologies open up opportunities to address existing inefficiencies, unscheduled downtimes and excessive rework by addressing hitherto unsolved problems.

Keywords
Continuous Process Improvement, Process Optimization, Focus Group

1. Introduction

Due to dynamically changing business environment, permanently increasing global competition, saturated markets and differentiated customer requirements (Bea & Haas, 2012), companies are confronted with the increasing complexity of their environment (Nadarajah & Sharifah, 2014). The globalization of markets and technological progress leads to a market that is becoming more and more dynamic (Griffith & Yalcinkaya, 2018). The shortened product life cycles and increasing customer requirements also mean that companies should strive for continuous improvement of their processes to remain competitive. For this purpose, process optimization methods can be used to identify and eliminate weaknesses in a process (Gericke, Bayer, Kühn, Rausch, & Strobl, 2013). Numerous optimization methods have developed over the years. The multitude of methods confronts companies with the challenge of choosing the right one. In addition to the companies size, the time and financial resources available are important factors for selection (Dombrowksi & Crespo, 2008). A method that another company used successfully, does not necessarily lead to success in the own company. Company-specific structures must be taken into account and methods must be adapted according to individual requirements (Baumgärtner, 2006). Large-scale enterprises, in particular, put a lot of effort into the optimization and automation of their production and business relevant processes in recent years. Therefore the question arise how executives of large-scale enterprises assess the future role of process improvement in a highly-automated manufacturing.

2. Continuous process improvement

Sustainable process improvement cannot be achieved by using a single process optimization method once. Instead, a continuous improvement process (CIP) should be initiated (Gisi, 2018). CIP practices include a combination of methods to conduct and coordinate ongoing process optimization. Herby it is essential to sustain employees motivation and ability to continually work towards the desired improvement (Benner & Tushman, 2003). One concept for such a CIP is the Japanese philosophy Kaizen translated as 'change for the better' (Gorecki & Pautsch, 2013). The central feature of Kaizen is the change in existing processes, in which all employees participating in the process are involved. On the one hand, this leads to an increase in motivation among employees and, on the other hand, the experience and knowledge of the employees can be used (Pohanka, 2014). Kaizen is the basis of the Toyota production system (TPS), which is known internationally as a system for reducing waste by using optimization methods (Santos, Wysk, & Torres, 2006).
In addition to the production systems, quality concepts can be used to improve processes. Among other things, these concepts pursue the goal of eliminating waste through the zero-error principle and the early detection of errors (Friedli, Seghezzi, Mänder, & Lützner, 2014). An example of such a concept is the TQM approach, in which an increase in quality is sought to differentiate itself from the competitors and at the same time to increase customer satisfaction (Dilworth, 1996). Such process improvement methods dictate the procedure to conduct optimizations in a well-structured manner. This also requires the empowerment of employees to participate in the improvement process and ensures that CIP makes good use of employees knowledge to enhance the inimitability of manufacturing processes. Consequently, a key to success for CIP is the assurance of employees interest in seeking optimization (Upton,1996).

3. Experimental research design

Since the purpose of this research was to seek insight into the experience, views and beliefs of process improvement methods in continuous manufacturing, the data required were essentially qualitative. Hence, focus groups were found to be a valid tool to explore the matter at hand in a dynamic manner. Nonverbal feedback and group interaction is utilized to challenge and probe the views of the 7 participants to generate a better understanding of the issues with and the potential of process improvements in manufacturing.

3.1 Virtual focus groups as a qualitative research method

Although researchers have been using focus groups since the mid-20th-century (Morgan, 1997), it remains a rather uncommon form of qualitative research (Barbour & Kitzinger, 1999). Focus groups are a common tool in user centered design, discussing products and its use with the target group. At its core, focus groups are group-interviews, where the researcher often utilizes a semi-structured approach to move the conversation along (Krueger & Casey, 2015). In contrast to classic group interviews with an traditional inquiry-response cycle the researcher gives room to open-ended questions and lets the group interact to move along the loose content structure (Kidd &

Parshall, 2000; Morgan, 1996). Therefore, focus groups are particularly suited for the consolidation of existing knowledge and to explore the depth and nuance of people's opinions and experiences (Litsoelliti, 2003; Gill, Stewart, Treasure, & Chadwick, 2008).
In contrast to other group methodologies, participants get the chance to express approval, to show disagreement with statements made by another participant or to add additional information by sharing personal beliefs and experiences (Ledermann, 2000; Kitzinger, 1994). Furthermore, the overall situation forces respondents to reconsider and reevaluate their own contributions to the discussion (Gibbs, 1997). In consequence focus group are not just the aggregation of individuals contributions (Osborne & Collins, 2001).
Since classic focus groups are usually carried out in a laboratory setting, its use is restricted to target groups that are available in sufficient numbers in the vicinity of the laboratory (Berg, 2001; Barbour, 2018). Virtual focus groups represent a suitable alternative to meet this challenge. A distinction must be made between synchronous and asynchronous focus groups. Hofmann, et al. (2012) were able to observe a deeper discussions and a higher group dynamic, since participants in a presence version tend to use excessive monologues. The synchronous virtual focus groups produced rational as well as emotional insights and tend to be more problem-oriented than traditional or asynchronous virtual focus groups.

3.2 Selection of experts and ethical considerations

The selection of experts is crucial for focus groups, as they heavily rely on participants' verbal contribution and interaction (Morgan, 1997). However, the research design does not allow for representativeness in a statistical sense. The focus rather lies on the representability of content than on individuals opinions and personal experiences in the highly automated manufacturing environment. This assumes that participants are rather representatives of the group under investigation than representing individual cases. Therefore, the purposive selection of typical cases is crucial (Gill, Stewart, Treasure, & Chadwick, 2008; Mayer, 2012). In the composition of the target group, attention was paid to a mix of hierarchical levels to get insights into different point of views and to foster discussion between this different experience levels and areas of responsibility. In addition to senior managers, project managers and team-leaders, with solid experience in manufacturing's process improvements as well as digitization, an in-house consultant was also brought into the group in order to be able to add additional perspectives. Care was taken to ensure that there was no direct professional relationship between the participants in order to obtain unbiased results.

Table 1. Overview of selected experts

Expert		**Company**		
Code	**Position**	**Sector**	**Revenue [Bio €]**	**Employees**
E1	Senior Manager Mechanical Manufacturing	Automotive	38,2	82900
E2	Production Manager Chip-Manufacturing	Automotive Supplier	4,9	9900
E3	Project Manager Manufacturing	Automotive Supplier	12,1	77000
E4	In-house Consultant	Automotive	-	110

E5	Team-Leader Production Planning	Pharma Industry	19,2	51000
E6	Project Manager Industrialisation	Automotive Supplier	3,8	17300
E7	Senior Manager Cast House	Iron and Steal Manufacturing	9,3	28800

Due to the fact, that focus groups expose participants verbal contribution to the judgement of the group (Walker, 2018), consent is a major ethical concern legitimizing the moderators actions to persuade participants to reveal intimate beliefs, personal experiences and feelings (Green & Hart, 1999). All participants gave written consent to participate on a voluntary basis, after the researchers outlined the usage of the gathered data and explained to what extend it will be disclosed to third parties. Confidentiality of the gathered data was ensured an anonymized analysis of transcripts and further access restrictions. However, the study was neither registered nor reviewed by an ethics committee.

3.3 Data Collection and procedure of the focus group

The virtual focus group was conducted on 2nd November via Microsoft Teams and lasted for approximately 100 minutes until attainment of saturation (Barbour, Doing Focus Groups, 2018). The proceedings were audio- and videotaped, to not only analyze the discussion, but also to evaluate non-verbal interaction, gestures and facial expressions. A semi-structured guideline was used including a short introduction to the topic and an initial exploration of experience with process improvement measures. Subsequently the moderator used open-questions to lead the discussion to the main topics, elaborating participants view of the importance of process improvement in manufacturing also sharing perceived hurdles and experience with pitfalls. Participants were also asked to assess the potential of further improvements in manufacturing. Finally, the importance of new technologies, respectively the digital transformation, for process improvements was discussed and its potential was elaborated.
Although virtual focus groups allow to easily record the sessions to later analyze gestures, facial expressions and non-verbal communication (Hoffmann, Olschner, & Schubert, 2012), several researchers were involved to handle technical issues while conducting the focus group. A moderator is essential to guide the discussion and to ensure that all relevant topics of the semi-structured guideline are covered. Special attendance was paid to the relationship developing between participant and to encouraging interaction of all group memebers (Rosentahl, 2016; Allen, 2014). Further, strategic summarizations were used to facilitate refinement of the groups point of view and individuals explanations.
Finally the verbatim, anonymized transcript was matched with conspicuous non-verbal signals from the screen recording and analyzed by the use of Kuckartz (2012) method. Basically, the records are divided into thematic main groups, which are subsequently divided into further so-called subcategories. Statements from the focus groups are assigned to these. The final step involves visualizing and interpreting of the categorized information.

4 Results and Findings

The findings from the focus group with executives from German large-scale enterprises can be grouped into the following categories:

- Executive views of the importance of process improvement in manufacturing
- Perceived hurdles when implementing process improvement
- Beliefs on the potential for increases in efficiency and effectivity
- Relevance of new technologies to enhance productivity

4.1 Importance of process improvement in manufacturing

Striving for effectiveness and efficiency in highly automated manufacturing has led to considerable process improvement efforts in recent years. It is precisely the dynamically changing framework conditions and the striving for flexibility that lead to highly complex structure, which would be incompatible with efficient implementation of the production processes without continuous improvement efforts. Process improvements are the most important factor for long-term success when it comes to avoiding unscheduled downtimes, inefficiency and waste, while ensuring high product quality. Not least, the process analysis is the decisive means to ensure that the optimization of individual process components, such as machinery, has no negative effects on the efficiency of upstream and downstream components (E3, E6). In the course of modernization and innovation projects, process analysis and the associated process optimization represent a crucial component in order to recognize dependencies at an early stage. Technical processes and its products are optimized with different objectives. In addition to costs, quality and safety aspects, ergonomics and environmental aspects are increasingly coming to the fore (E4, E7). Process security always ranks a matter of course highest for the process operator. Process optimization therefore only promises to be successful if all criteria are taken into account during the optimization. Therefore, only continuous and sustainable implementations are achievable, making process improvements a major task for highly automated manufacturing.

4.2 Perceived hurdles in manufacturings' process improvement

Despite intensive efforts, different automation solutions are still in use in most production plants. Against this background, the cross-system, unadulterated recording of complex processes is a major problem when it comes to analyzing and improving existing processes. Due to the heterogeneity and complexity, suitable methods and additional tools are essential in process optimization (E6, E2). There was disagreement about whether the local machine must be the starting point for the efforts or whether all optimization potentials must be based on a global perspective. It is crucial, however, that the dynamic process behavior must ultimately be recorded at characteristic points (E7). Another challenge is seen in the comprehensive identification of the decisive measuring points. In particular, problems arise in the analysis and the resulting improvement efforts, if the interactions between individual process components does not become transparent. Internal program flows are usually not observable in detail from the outside. Usually only their effects become visible (E3). In addition, it is difficult to draw conclusions about the internal software-process from the visible and observable process behavior. In general, the unit under question are so-called distributed system. Consequently, several processing systems are used. Several concurrent software programs interact with one another via various communication mechanisms on several controls, which results in chronological and functional interactions that further increase the complexity. Another challenge is that hardly any sequence is reproducible in

automated technical processes. That implies a lack of time determinism, since task runtimes in controls heavily depend on the process status, current production, external environmental influences or the current system status, such as wear and tear. This leads to a level of complexity that humans can no longer manage without digital aids. Ultimately, additional tools are needed that must record the various process data synchronously. This is where further hurdles arise in practice. Different analog and digital signals must be recorded in a fail-safe, continuous and synchronal manner. Interactive, multimedia analysis instruments are necessary to analyze the enormous amounts of recorded data. Here people come to the fore as a further potential source of error (E2). The process optimization also represents a creative challenge, which presents the risk of a one-sided view by the engineers involved. An important principle for success is the development of specific fields of action for revealed weak spots. Necessarily, a global perspective must be adopted. However, the implementation of innovation workshops with interdisciplinary teams using creative techniques continues to meet with incomprehension and resentment among the long-established workforce. A well-structured and stringent moderation of the entire process improvement process is therefore essential, but at the same time represents a major challenge.
The sustainable implementation of process improvement methods and, in particular, the selection of suitable methods and the right personnel represent a further hurdle. The participants see problems particularly with the operational implementation and the willingness to bear the necessary changes in the long term. On the other hand, this is also seen as a decisive opportunity for a sustainable improvement project. Especially when ergonomics and environmental aspects come more into focus.

4.3 Beliefs on the potential for increases in efficiency and effectivity

Even though enormous efforts have been made to optimize existing production processes in the past decades, there was consensus on the existence of considerable potential for further improvements. This starts with the need to further optimize information flows, indirect areas and any supporting processes. It ends with the use of new technologies, which open up new dimensions for improvement. Finally, there is still a need for action in the implementation of continuous improvement processes itself. Indirect areas, in particular, and its interface to production still hold considerable room for improvements in order to fully exploit the effects of previous process optimization efforts in manufacturing. Overall, the estimated potential for improvement ranges from 6 to 15 per cent. That heavily depends on the individuals field of responsibility and its integration into the product creation process.
Decentralized improvement processes are expected to be the most promising approach to significantly increase the efficiency and effectivity in large-scale enterprises manufacturing (E1, E4, E7). Efforts to date have essentially focused on optimizing the technical aspects of the production methodology. However, due to this limited perspective, the existing efficiency potential can only be exploited to a limited extent. Therefore, companies must aim for an integration of the human capital for process improvement. For this reason, it becomes important to integrate management and behavioral aspects into the decentralized optimization efforts. The operational implementation of a continuous improvement process must become the responsibility of the worker, whilst the manager remains responsible for the result of the improvement efforts.

4.4 Relevance of new technologies to enhance productivity

The participants expect significant increases in productivity from advancing digitization. In particular, there are two main topics promising an enhancement of productivity in the medium-term:

- The use of worker assistance systems on the shop floor
- The use of Big Data Analytics to investigate the cause of errors

While the increasing automation and improvement of production lines and processes will sooner or later take hold, the experts see the substantial potential of digitization in addressing hitherto unsolved problems. An essential goal is to minimize unscheduled downtime and inefficiency on the one hand, and excessive rework on the other. The main problem is to actually uncover the cause of errors. Although the problem is often immediately apparent, the highly complex processes often raise the problem that the actual cause cannot be identified directly (E3, E7). This is not least due to the fact that individual process steps cannot yet be fully digitally recorded and monitored. "At this point, a few small black boxes become a black box for the entire process"(E1). For example, during the sand modeled casting process, the problem of insufficient residual wall thickness occurs, which leads to rejects of over 18%. Despite long experimentation, the cause could not be assigned to the corresponding process step, and further measures have so far failed (E4). Digitization is supposed to help. However, experts argue that in fact a continuous digital recording is not always possible. Especially when the component changes its physical state during the machining process, it is almost impossible to record and model data directly. The most convenient option is to control environmental variables, only (E7). "The uncovering of cause-effects chains becomes a guessing game"(E3). In consequence, all agreed that manufacturers should rely more on big data analytics to address a cycle of problems that lead to unscheduled downtime, inefficiency and excessive rework. Six Sigma proves to be an established and customer-oriented improvement approach with focus on the analysis of company processes to eliminate causes of errors and process deviations. Due to the increase in machine-generated data and the resulting rise in the volume of data, it is no longer possible to determine cause-effect relationships between variables by applying Six Sigma alone. Machine Learning methods are a useful addition to the Six Sigma statistical toolbox, especially when analyzing complex processes with many influencing parameters.

In this context, it is important to make use of existing technologies to rule out humans as a source of error. The use of worker assistance systems is associated with high expectations to not only reduce error rates through additional in-process controls and precise work instructions (E6), but also for precise records, that in consequence increases the predictability of personal placement (E1, E2). Employees can be optimally trained, motivated and deployed through customizable systems. Finally yet importantly, this should be a further step towards integrating human capital for process improvement. In addition, production will become more flexible, representing an important step towards smaller batch sizes. An important factor in ensuring flexibility is the shift of responsibilities and decision-making tasks from the management level to the affected areas on the shop floor and the reduction of escalation loops. Nevertheless, the available volume of data and information is almost impossible for humans to comprehend and penetrate. Workers are hardly able to cognitively penetrate corresponding systems without supporting or supplementary technologies. AI-based decision support systems can help workers make decisions for the shop floor by providing evaluated options for action. Finally, work safety can be further increased through specific warnings without "daily reminders" (E7). On the other hand, there are concerns that necessary process changes will be difficult for employees and that work councils will slow down its application. Most worker assistance systems are equipped with numerous sensors recording a huge amount of data that might create a feeling of monitoring and control among employees (E4). Data processing and its access are often opaque. An extensive data acquisition can lead to increased competition among employees and shifts that ideally leads to an increase in performance, but is also accompanied by psychological pressure with highly negative effects. Monotony and cognitive underuse in severely restrictive, controlling systems may amplify a negative effect on motivation, health and long-term work ability. The main task will therefore be to ensure ethically justifiable use in order to be able to use the full potential for increasing productivity.

5. Conclusion

Although large-scale enterprise already invested a lot of effort into the automation and optimization of their manufacturing processes there is still room for significant improvements. On the one hand continuous process improvement continuous process improvement aims for steady but incremental improvements. On the other hand new technologies, such as big data analytics or worker assistant systems open up opportunities to tackle existing inefficiencies, unscheduled downtimes and excessive rework by addressing hitherto unsolved problems. An highly automated manufacturing results in such a complexity that additional digital tools are needed to gather and analyze a rash of data. Here people come to the fore as a further potential source of error. Any process optimization also represents a creative challenge, where one-sided perspectives must be prevented in order to identify best measures. Necessarily, a global perspective must be taken taking digitalized solutions into account. However, it is not sufficient to digitally transform your manufacturing, your entire organization needs to be digital. This is the prerequisite to identify all bottlenecks to be optimized. Consequently, both digitalization and continuous improvement must rely on fundamental organizational change as well as on the adoption of a suitable mindset. Every employee has to support the transformation and must be incorporated into decentralized improvement processes, which are expected to be the most promising approach to significantly increase the efficiency and effectivity in large-scale enterprises. Efforts to date have essentially focused on optimizing the technical aspects of the production methodology. However, due to this limited perspective, the existing efficiency potential can only be exploited to a limited extent. Therefore, further research should concentrate on the integration of the human capital for process improvement and find ways to to implement an suitable mindset to integrate management and behavioral aspects into decentralized optimization efforts.

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