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Manufacturing Change Management – A Survey On Current Challenges, The State Of Digitalization And The Application Of Change Impact Analysis In Industrial Practice

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Abstract

Modern manufacturing companies operate in a complex and highly dynamic environment. External factors such as new legislations and customer demands, as well as internal factors such as fluctuations in production rates and frequent product changes, make it essential for companies to respond quickly and effectively to changes of all kinds. Scientific literature already provides various processes and methods to manage Manufacturing Changes (MCs) efficiently and to precisely assess their possible impacts. Building upon the existing literature, this survey-based study aims to gain practical insights into the implementation of Manufacturing Change Management (MCM) and Change Impact Analysis (CIA) in real-world industrial settings. By examining the current challenges and exploring the state of digitalization, this research provides valuable insights to complement and further develop the existing theoretical frameworks. In order to gather diverse knowledge from experts across various industries, a web-based survey was conducted, with 99 participants representing 15 different industries. After introducing the necessary theoretical foundations and the current state of research in MCM literature, this contribution describes in detail the methodology of the survey development. The survey findings are then outlined and discussed thoroughly. Finally, the contribution concludes by offering an outlook on future research perspectives based on the identified industry challenges.

Keywords

Manufacturing Change Management; Change Impact Analysis; Digitalization; Web-based Survey; Industrial Practice

1. Introduction

Manufacturing companies are facing an increasingly turbulent environment influenced by external and internal factors [1]. For instance, shorter innovation cycles lead to a more frequent introduction of new technologies, which, combined with more rapidly changing customer demands, lead to shorter product life cycles (PLC). Political and legal factors also contribute to the turbulent environment [2], particularly regarding the transformation towards sustainable manufacturing. Both, external and internal drivers favor the increasing number and variety of Manufacturing Changes (MCs) [3]. The consequences of inefficiently managing these changes are far-reaching and can, among other things, pose existential risks for factories [3] and entire companies. A functional Manufacturing Change Management (MCM) is therefore essential for the effective and efficient management of MCs and thus for securing the competitiveness of companies in the turbulent environment [4]. In particular, processes for the systematic management of changes and

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methods for the precise analysis of the potential impacts of changes are essential in a functioning MCM system.

This contribution focuses on the industrial application of MCM and aims to present the status quo of MCM in industrial practice. In addition to the application of change processes and impact analysis, current challenges and the potential of digitalization are examined. To this end, a web-based survey with experts from various manufacturing industries was conducted.

The remainder of this contribution is structured as follows. Section 2 outlines the research approach of this study. Section 3 introduces the necessary terms and definitions as well as similar studies conducted in this area of research. The following section describes the structure of the study. Section 5 introduces the study's participant distribution, while Section 6 details the study's outcomes. Section 7 discusses the findings and limitations and provides an outlook for future research. Section 8 concludes the study.

2. Objective and research methodology

The goal of this contribution is to analyze the contemporary significance and application of MCM in industrial practice. The focus is particularly on different change processes and approaches for Change Impact Analysis (CIA) as well as current challenges in the field of MCM. Furthermore, the state of digitalization and the potential of applying digital tools are examined.

To achieve this goal, a survey was developed following the six-step questionnaire development methodology according to [5] (see Figure 1). Due to numerous advantages, such as reaching a large number of experts at a relatively low cost and the immediate availability of data [6], a web-based survey was chosen as the data collection method in the first step of the methodology. For the question-and-answer types in step two, mainly closed and semi-open questions were used in order to achieve the highest possible information density and enable a targeted evaluation [5]. In step three, the questions were formulated using a top-down approach, in which the overarching topics to be covered are first defined and subdivided into further topic blocks. Then, individual questions are derived from these using simple and unambiguous language [7]. The respondents' willingness to participate is influenced by the questionnaire's content as well as the design of the form and layout. In principle, attention should be paid to an appealing appearance, which can be achieved by keeping the font size and the numbering consistent. This is also closely related to the survey tool chosen in step five. According to [8], the survey software should have a participant management system, a user-friendly interface, and reliable and secure data management. Taking into account several other economic and functional criteria, the software "easy feedback" [9] was chosen. Once the questionnaire is developed, it is necessary to test it before it goes into the field. This is done by means of a pretest, in which a selected group of people, who should be similar to the target group, carry out the test under actual test conditions [10].

The quality of research work is largely dependent on the quality of the data and therefore on how the survey is conducted and how the questionnaire is designed. Scientific literature usually distinguishes between three primary quality criteria: objectivity, reliability and validity. Additionally, there are secondary criteria such as standardization, comparability, economy and usefulness, which can all be divided into further sub-criteria [11,12]. However, [13] state that the choice of criteria is highly dependent on the use case and the people conducting the survey. They distinguish between general criteria, which can be applied to all surveys, and specific criteria, which should be used for complex tasks such as the extrapolation of conclusions or the feasibility of diagnostic decisions based on the survey results. The specific criteria require knowledge of classical test theory, item response theory, and advanced analysis techniques. As the requirements for the secondary criteria exceed the requirements for this survey, the general criteria are considered to be entirely sufficient. These include objectivity of implementation, objectivity of evaluation, objectivity of interpretation, economy, usefulness, appropriateness, fairness, and non-falsifiability, all of which are considered in this survey.

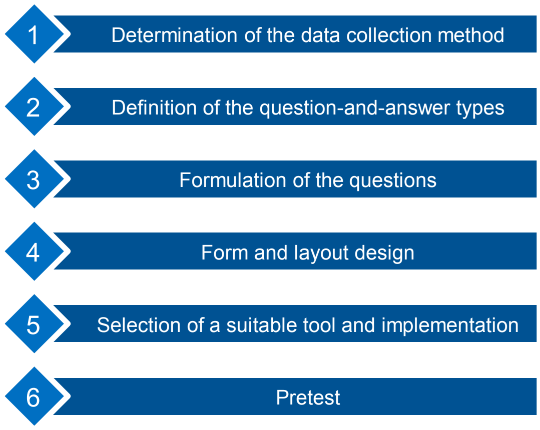

Figure 1: Steps of the questionnaire development according to [5]

3. Terms and definitions

3.1 Fundamentals on Manufacturing Change Management

According to [14], changes in manufacturing companies can be distinguished primarily by the object of change, whereby a differentiation is usually made between three different objects: the product, the production (consisting of technical and logistical processes as well as production facilities), and the company organization [14]. Changes to the product and the factory can be grouped under the term Technical Changes, as opposed to Organizational Changes [15]. In contrast to the management of changes in production, also called Manufacturing Change Management (MCM), the management of changes to the product, called Engineering Change Management (ECM), has already been widely researched. According to [16], ECM primarily refers to "the organization and management of the process of product changes". The goal of ECM is to ensure that changes are implemented effectively and efficiently without compromising the product's functionality, quality, or safety. The first clear definition of MCM is provided by [4]: "Manufacturing Change Management refers to organizing and controlling the process of making alterations to a factory. This includes the totality of measures to avoid and specifically front-load as well as efficiently plan, select, process, and control Manufacturing Changes" [4]. In addition to minor changes, such as parameter changes on machines, significant changes, such as a redesign of the factory layout, can be considered an MC. ECM and MCM are summarized under the term Technical Change Management (TCM).

3.2 Change Impact Analysis

A fundamental aspect of both ECM and MCM is the CIA, which aims to assess the potential impact of proposed changes [17]. It involves a systematic evaluation of the impact of a change on resources, such as equipment, materials and personnel, as well as on related activities and systems [18]. This analysis helps to identify potential risks, dependencies, and interrelationships among different components of the product or the factory system, enabling informed decision making and effective planning for change implementation. Especially in ECM, many methods have been developed to analyze the impact of changes on products as in [19–21]. In recent years, approaches for CIA in manufacturing systems have also been developed [22], [17], [23].

3.3 Past studies on MCM

To determine the current state of research in the MCM literature, a comprehensive literature review was conducted using the Webster & Watson methodology [24]. The literature review focused on studies that examine the industrial practice of TCM and specifically MCM.

The literature review identified six significant publications that present studies on either ECM or MCM. While the studies by [25–28] provide valuable insights into ECM, the studies by [29,30] focus on MCM. Both studies underscore the growing importance of MCM and offer first insights into possible advances through digitalization.

Despite the valuable insights provided by the study in [29], which included a significant number of 85 relevant datasets, it is worth noting that the study dates back to 2015. In addition, a significant portion of the participants (70%) belonged to the automotive and machinery industries. On the other hand, the more recent study [30], conducted in 2021, captured a smaller sample size of 34 participants, but still showed a predominant focus on the automotive and machinery industries (76%). Given the rapid advances in the field of manufacturing, particularly in the area of digitalization, there is a clear need for a new study that can provide a fresh perspective and encompass a more extensive and diverse pool of participants.

4. Structure of the study

The questionnaire consists of 36 questions, some of which are combined in a matrix format. Only mandatory questions were used to prevent skipping or over-reading individual questions. Filter questions were used to ensure that previous answers were taken into account. As a result, the number of participants for each question varies throughout the questionnaire. The survey is divided into four sections (Figure 2). At the beginning of each section, the necessary definitions are explained. The first section deals with the characterization of the field of participants. The second section is dedicated to MCs in the industrial practice. The third section analyzes the current application and different approaches of MCM, especially the CIA. The last section deals with the state of digitalization and its potential in MCM.

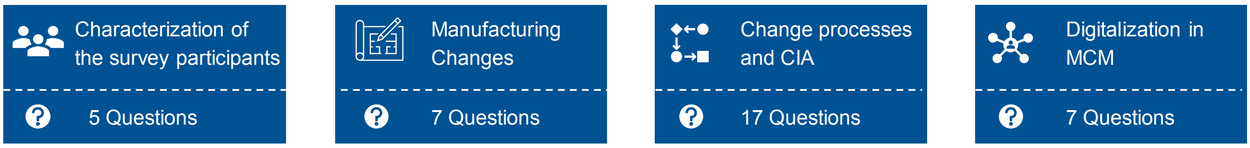

Figure 2: Structure of the study

5. Study participants

After contacting over 250 people through personal contacts of the authors and several mailing lists, a total of 108 people participated in the survey. Of these, 92 completed and returned the questionnaire. In order to include the insights of those experts who did not complete the questionnaire in full, and thus increase the number of useful datasets, a minimum of 16 answered questions, representing more than the first two sections of the questionnaire, was defined as the threshold for inclusion in the evaluation. This increased the number of records evaluated to a total of 99 questionnaires.

The study represents a broad range of participants. In total, the study includes participants from 15 different industries. 56% of the companies thereby surveyed belong to the mechanical engineering and automotive sectors. Various sectors such as medical technology, biotechnology, steel processing and automation technology were grouped under "other". Figure 3 shows the distribution of respondents by industry.

The study also represents a wide range of company sizes. Almost half (49%) of the 99 respondents indicated that they work for a company with over 10,000 employees. Nearly three-quarters (71%) of all respondents work for companies with over 1,000 employees. 13% of the participating companies have more than 250 but less than 1,000 employees. Only 5% of the participating companies have less than 50 employees.

The survey also covers a wide range of production types. Almost all (94%) participating companies have a production facility, with a large series or mass production together representing the dominant production types at 62%. Small batch production is represented in the survey by 17%, and individual one-off production by 14%. The high proportion of production companies is due to the scope of the survey, which was aimed at employees with a production background. The remaining 6% are consulting companies that do not possess production facilities but are currently involved in production-related projects.

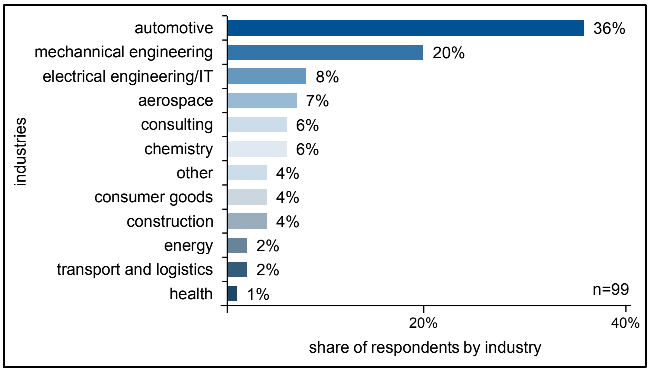

Figure 3: Distribution of the respondents by industry

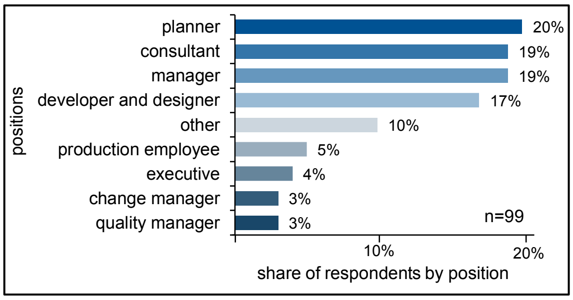

Figure 4: Distribution of the respondents by position

More than half of the respondents (58%) are involved in planning, consulting and management. Other roles include development and design (17%), production (5%) and executive roles (4%). Technical administrators, process planners, and product managers were grouped under "other”. Figure 4 shows the respondents' positions in the company.

6. Survey results

6.1 Importance of MCM

54% of the respondents currently consider MCM important or very important. In the future (next five to ten years), its importance will increase significantly. In fact, 94% of the respondents rate MCM as important or very important in the future. Figure 5 shows the respondents' assessment of MCM’s current and future importance.

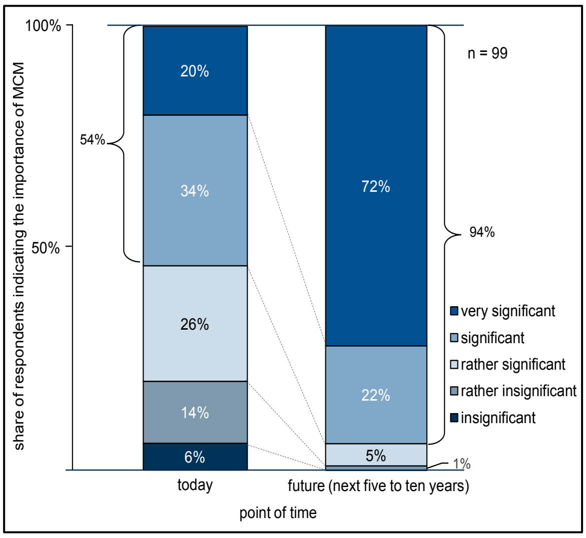

Figure 5: Current and future importance of MCM

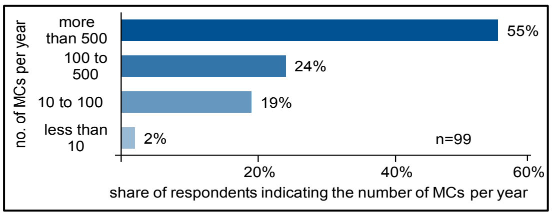

Figure 6: Number of MCs per year

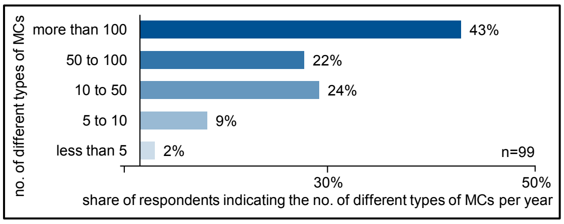

Figure 7: Number of different types of MCs per year

A large proportion of the respondents (55%) indicate that they record more than 500 Manufacturing Changes per year (see Figure 6). In addition, 24% of the respondents conduct between 100 and 500 MCs annually. This means that, on average, 79% of the respondents make an MC at least once every three days. Not only is the number of MCs high, but also the variety. Currently, almost half of all companies have to deal with more than 100 different types of changes per year (see Figure 7). In addition, 85% of the respondents expect the variety of changes to increase significantly in the years to come.

6.2 Manufacturing change process

As shown in Figure 8, about half (52%) of the respondents use at least one defined process specifically for MCs. Just under a third (32%) do not have a separate MCM process but have at least one process for product changes that is also used for MCs. 5% have a product process that is not used for MCs and 11% have neither an MCM process nor an ECM process.

When companies do have a process for handling MCs, almost half of them (48%) have individual processes for the different types of changes. The remaining 52% of the companies that have a process for managing product and process changes have a holistic process for the different types of changes.

In this context, many respondents indicated that the process currently used in their company has shortcomings. The most common criticisms are the lack of flexibility and the inability to adapt the process to changes. Other process shortcomings include a lack of support in the selection of technologies and methods.

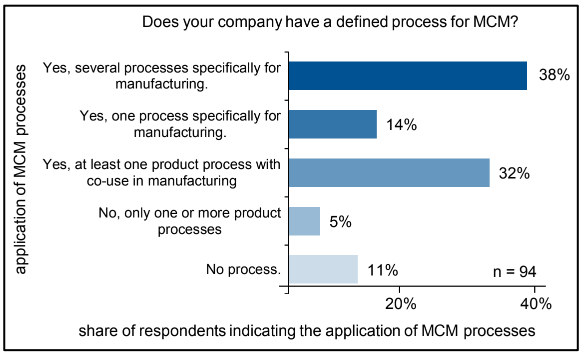

Figure 8: Change processes in industrial practice

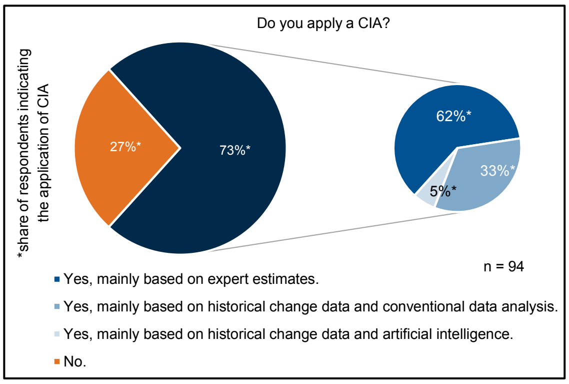

Figure 9: CIA in industrial practice

6.3 Change Impact Analysis

27% of the respondents indicated that they do not perform a CIA (see Figure 9). The main reason given for this was the cost and the effort of applying a CIA. The remaining companies (73%) use a CIA, 62% of which is based on expert estimates. 33% of the respondents use historical change data in combination with traditional data analysis for the CIA. The remaining 5% use historical change data and artificial intelligence methods for the CIA.

6.4 Status of digitalization of MCM

Today, more than two-thirds (68%) rate the digitalization of MCM as significant or rather significant. In the future, this importance is expected to increase significantly. A total of 98% of all respondents rate the digitalization of MCM as significant or rather significant in the coming years.

89% of the respondents currently use digital support to manage MCs. The most commonly used software programs are SAP, Excel, and tools for workflow management. Artificial intelligence and machine learning are used by 10% of the respondents for digital support. Other digital tools were grouped under "other", including Microsoft Teams, SharePoint/Jira, Windchill, enterprise resource planning systems, and email.

In summary, many companies see great potential in digitalization to support MCM. For example, only 3% of the respondents indicated that the potential of digitalization for MCM is fully exploited in their organization, while 72% feel that the potential is not fully exploited or not exploited at all. In particular, the use of digital technologies in specific process steps and improving employees' digital skills are seen as major potentials in MCM (Figure 10).

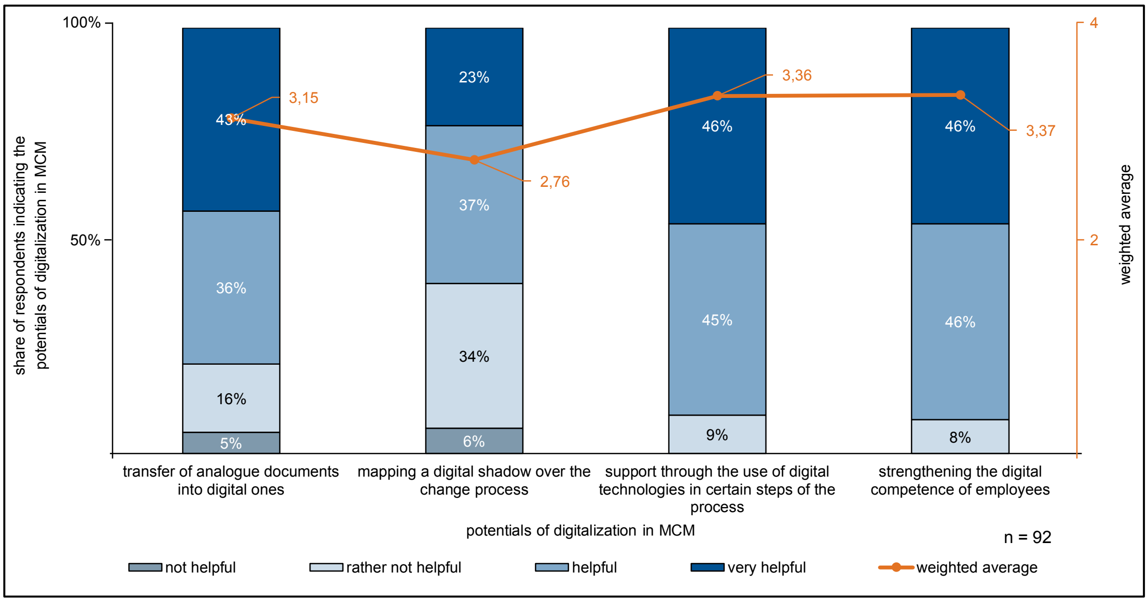

Figure 10: Potential of digitalization in MCM

6.5 Challenges and potentials for improvement

In addition to digitalization, the survey identified several other challenges and opportunities for improvement in MCM today. The most significant potential for improvement is seen in learning from changes. A total of 68% of the respondents see great potential for development in this area. Further potential is seen in communication, meeting deadlines, documentation, and planning. It can be concluded that human factors in particular play an essential role in improving MCM. Figure 11 shows the potential for improvement in MCM.

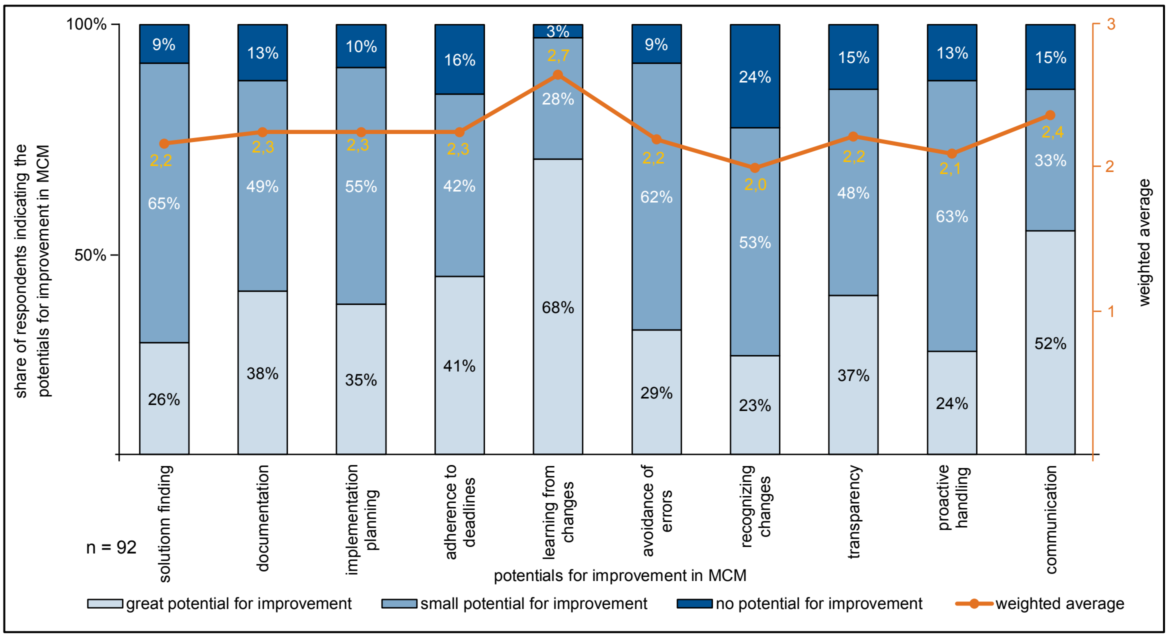

Figure 11: General challenges and potential for improvement in MCM

7. Discussion

The quality criteria presented in section 2 could be achieved as follows. The objectivity of the implementation was ensured by using the same questionnaire and additional information for all participants and by selecting participants with similar knowledge and manufacturing backgrounds. Only the implementation time varied, but this can be neglected in this survey as it was not a performance test or anything similar. In questionnaires with mostly bound answer options, the objectivity of evaluation is almost exclusively given [13]. The objectivity of the interpretation was ensured by the fact that different persons interpreted the data and came to the same conclusion, which fulfills the objectivity of the interpretation according to [13]. The costs of the study were very low due to the online survey. Participation took an average of 18 minutes, demonstrating the study's economy and reasonableness, as participants were not exposed to extraordinary stress as they were free to complete the task at their own pace. The usefulness of the study was emphasized by several participants and was also partially reflected in the responses. The results do not lead to systematic disadvantages for certain persons, which is why the study can be considered fair. The non-falsifiability cannot be clearly demonstrated; at this point, it must be assumed that the experts answered the questions to the best of their knowledge and belief. The high number of participants ensures that individual outliers are compensated for.

In summary, this study provides a current and comprehensive overview of the application of MCM. With 99 participants, the study exceeds previous surveys on this topic. The results of this study are suitable to show trends and developments in MCM, especially in large companies. A particular strength of this research is that it represents the knowledge of participants from a total of 15 different industries and thus provides a differentiated picture of the current application of MCM in industrial practice.

8. Summary and Conclusion

In this contribution, a study was conducted to analyze the application of MCM and CIA in industrial practice, as well as the current challenges and state of digitalization in MCM. A web-based survey was conducted with 99 participants representing over 15 different manufacturing industries. The survey provided insights into MCM from the current industry perspective. The importance of the research area today and in the future was recognized by a large number of participants, as many companies report that the volume and variety of MCs constitute a significant challenge. In summary, the following key takeaways can be derived from the results of the study:

- MCM processes and CIA are applied by the majority of companies.
- Many processes lack the flexibility to handle the wide variety of changes.
- Most processes lack the technological and methodological support to manage MCs efficiently.
- Human factors play an essential role in the success of MCs.
- Digitalization is not yet far advanced in MCM but is considered to have a great potential.

The findings of this study reveal a wide range of diverse challenges in Manufacturing Change Management, encompassing human, technological, and organizational aspects. Moving forward, future research activities should prioritize holistic approaches encompassing all facets of MCM, aiming to foster more effective and efficient handling of the large number and variety of MCs. This may involve the integration of advanced technologies, such as artificial intelligence or virtual reality, alongside the development of comprehensive and flexible frameworks and methodologies that support decision making and human involvement in change management processes.

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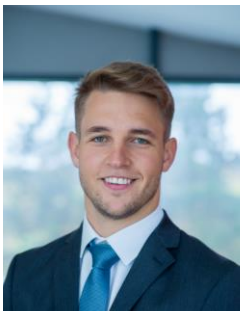
Biography



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