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Approach for stakeholder identification in Manufacturing Change Management

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Abstract

Resilience, agility, and flexibility are considered key factors in maintaining the long-term competitiveness of manufacturing companies. In addition to assembly and production systems that offer a high degree of reconfigurability, the intelligent design and implementation of the change management process is an important prerequisite for this. In this context, the identification of the affected employees and departments during change initiation, planning, and implementation is necessary to ensure the consideration of all relevant perspectives on the intended change, e.g. concerning the resulting change effects. Especially in medium-sized and large companies, this is complicated by a multidimensional division of tasks and responsibilities. Therefore, this paper presents a methodological support for stakeholder identification in Manufacturing Change Management. Through an extensive literature research and several expert interviews, relevant dimensions for the description of technical changes and the responsibilities of employees are defined. Based on this, the entire approach is described from the initial modeling of the company's internal organizational structures to the application and interpretation of the results. The evaluation and validation were carried out in cooperation with a globally operating mechanical engineering company in southern Germany. Five different use cases, including the redesign of several assembly workplaces, were analyzed and evaluated through expert interviews.

Keywords: Manufacturing Change Management; Stakeholder Identification

1. Introduction

The adaptability of factories and production systems is considered as a key factor in research for the long-term and economically successful persistence of manufacturing companies [25, 20]. External factors, such as legislation or customer requirements, and internal factors, such as the factory life cycle or continuous improvement processes, lead to a permanent need for change. Manufacturing Change Management (MCM) describes the process by which changes in factories can be implemented in a structured and efficient manner. It can be defined as "the organization and control of the change process in a factory, which comprises the totality of measures for avoiding and selectively bringing forward as well as efficiently planning, selecting, handling and controlling manufacturing changes" [12]. An important step within the process is the identification of the affected stakeholders, whether at the departmental level or the individual or corporate role level [12]. Failure to involve affected stakeholders may result in missing information and poor communication, thus leading to underestimated changes and wrong decisions [4]. This carries the risk of high financial outlays and production delays [16]. However, although existing works emphasize the importance of stakeholder identification (SI), there is no systematic support that addresses the large variety of technical changes. In current industrial practice, SI is mainly performed based on the experience of the change coordinator [23, 21], which is a problem especially in the case of employee turnover. In addition, SI is complicated in medium and large companies by a multidimensional distribution of tasks and responsibilities, e.g. across different plants and products. Therefore, this contribution aims to present a company-independent approach to systematically support SI of manufacturing changes (MC) at an early stage of MCM.

The remainder of this work is structured as follows: Chapter 2 provides an overview of the current state of research and the resulting need for action. Chapter 3 presents relevant description dimensions of stakeholders and MC. Chapter 4 describes the entire approach, starting with the initial information collec-

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tion and ending with the interpretation of the obtained results. Chapter 5 presents the results of an initial industrial application and evaluation at a global engineering company. The paper ends with a summary and an outlook on future research activities.

2. State of the art

Relevant preliminary work was identified by a structured literature search according to Jahangirian et al. [9]. As part of this two-step approach, which considers both backward and forward searches, several literature databases (including Scopus, Google Scholar, and IEEE) and scientific journals were analyzed. Relevant prior work was divided into approaches for the systematic description of MC and approaches for stakeholder identification in change management.

2.1. Relevant preliminary work

Multiple authors have already presented description models for technical changes. In particular, with regard to the systematic description of product changes, commonly referred to as Engineering Changes (EC), numerous approaches have already been presented [e.g. 10, 27, 1]. In contrast, only a few approaches deal with the systematic description of MC [e.g. 2, 20, 25]. The most comprehensive description model was developed by Koch [12], which combines the previously published approaches to describe MC and EC. In total, 20 general and 35 specific attributes were presented, which can be categorized as specification, characterization, and coordination & evaluation. However, a systematic use of these attributes for SI has not yet been described. This is partly due to the fact that some of the attributes mentioned so far are not sufficiently detailed. E.g. the attribute "Localization" is considered as an aid for the "selection of specific employees, teams or responsible persons within the various departmental functions", but not specified further [12].

Only a very limited amount of preliminary work provides support for SI in technical change management. Some data-based approaches analyze the relationships between process participants [17] or provide direct decision support on which relevant departments to contact [23]. However, these approaches rely exclusively on historical change data, which cannot provide support in all cases due to the often novel nature of a change. Koch [12] uses the defined attributes and provides general guidance on which departments to contact in which cases based on a literature review and industrial case studies. There is no company-specific adaptation or consideration of the characteristics of the attributes (e.g. financial impact: low, medium, high). Therefore, the provided support is too general to consider the multidimensional division of responsibilities between stakeholders, e.g. with regard to different plants, products, or production areas. This results in an imprecise and error-prone SI. Furthermore, like the data-driven approaches mentioned above, the approach is limited to the identification of affected departments. Support for the identification of affected persons, roles, or teams within departments has not been considered so far.

2.2. Shortcomings

The presented overview of relevant preliminary work shows that existing process models include the step of SI and emphasize its importance, but a systematic support of SI within MCM for industrial practice is missing. Existing approaches only provide very general indications on SI which do not the allow the adaption to individual companies. Therefore this work aims to provide a systematic support for SI in the early phases of MCM. To achieve this, three central goals shall be achieved. First, relevant dimensions of change description are identified and further detailed, enabling a systematic alignment between MC and the distribution of responsibilities within the company. Subsequently, the information obtained is used as a basis for the development of a holistic method for SI, covering all steps from the initial information collection to the interpretation of the results. The final step of this work aims at evaluating the industrial applicability based on real industrial use cases.

3. Description of responsibilities for stakeholder identification

In this section, all relevant dimensions for modeling the distribution of responsibilities relevant for MCM are presented. These dimensions describe the characteristics (e.g. urgency or cause) and also the spatial and organizational localization (e.g. affected departments or plants) of a change. The systematized description of responsibilities is the basis of the developed approach, as it is later compared with the characteristics of new changes, which are described according to the same scheme. In the first subsection, the research procedure for identifying and validating the description dimensions is presented. Subsequently, all dimensions and the corresponding sub-dimensions are described in detail.

3.1. Approach

The basic motivation for the matching between the responsibilities of the employees and the MC is derived from the concept of task analysis and synthesis [13]. According to this concept, the overall task of a company, e.g. the development and manufacturing of physical products, is divided into sub-tasks until concrete activity profiles are achieved. Stakeholder's responsibilities can therefore be described in their totality with the gathered dimensions. The initial collection of potentially relevant dimensions was conducted as part of a systematic literature review according to Jahangirian et al. [9]. After the literature-based research and collection of dimensions, a validation was carried out. For this purpose, nine experts from the fields of product development and production engineering were interviewed using semi-structured interviews, as proposed by Galleta [7]. The experts were selected from the employees of the application company and the industrial contacts of all authors. It was ensured that all interviewees have experience in change management or related areas. Table 1 provides an overview of the experts and their roles in the companies.

Table 1. Participants of the expert interviews

Industry	Position
Mechanical Engineering	Project Leader Production Engineering
Automotive Supplier	Project Leader Technical 3D-Design
Engineering Consultancy	Project Leader Technical 3D-Design
Mechanical Engineering	Process Planning Engineer
Automotive Manufacturer	Change Manager
Automotive Supplier	Technical 3D-Design
Mechanical Engineering	Director Production Engineering
Mechanical Engineering	Project Leader Production Engineering
Medical Technology	Leader Process Development and Change Management

3.2. Dimensions

The conducted extensive literature research with a subsequent expert validation by means of a semi-structured interview delivered a total of eight dimensions. The industry experts confirmed the selection derived from literature. All dimensions were considered relevant, albeit with varying degrees of importance. They are presented individually in the following:

Change Causes: Change causes in MCM can be classified in *Manufacturing, General Occurrences* and *Product Development* [12]. The category *Manufacturing* deals with the factory life cycle, complications, and MC themselves. *General Occurrences* comprise changes of regulation, technologies, business operations, Kaizen, and procurement. *Product Development* refers to the product life cycle, failures and mistakes during product development, and EC themselves. If necessary, the causes can be further specified by the company when adopting the approach. For example, the dimension *Complications* could be expanded to include a specification of the Key Performance Indicators (KPI) concerned.

Change Impact [18, 23]: This dimension describes the direct and indirect effort related to the implementation of a MC. It encompasses the sub-dimensions *change cost* and *available or needed time* for change implementation. These sub-dimensions allow estimating the intensity of the produced change impact. The change impact can also be reflected in relevant KPI of a company.

Change Complexity: The complexity of a MC is composed of the sub-dimensions *interconnectedness in the production [20, 16]*, *change requirements*, *change challenges* and *change risk*. *Interconnectedness* describes the energy, information, and material flows within the production plant of the affected change object [16]. The *change requirements* comprise technical [19], layout and human requirements [14]. Technical requirements comprise all technical aspects of MC [8]. Human requirements deal with the fulfillment of employee requirements in the workplace. Some examples are ergonomics and motivational aspects [14]. While the *challenges* related to the MC depend on the degree of novelty of the change, the *risk* of the MC estimates the consequences of a wrong decision, e.g. production delays or dangers for the employees[1].

Change Propagation: It describes "the process by which a change to an existing system design triggers at least one additional change to the system or any associated activity, incident, or deliberate decision within the engineering system environment, that would not have been otherwise required" [18]. A technical change could lead to other changes at the product or process level [23]. The propagation of a MC could be available either in the form of the *probability of propagation* or the *number of additional changes* created.

Structural Organization: This dimension comprises the way a company is organizationally structured as defined by Wiendahl [24]. Companies are often structured hierarchically, which leads to organizational units or departments. The activities of a company are carried out by the employees, which are part of an organizational chart. It allows to identify the location within the organizational chart to which the stakeholders belong, thus identifying the production or assembly part they work at, the department, sub-departments all the way to project team, which they belong to. Information about the position of the employees within the organizational chart fosters a more transparent responsibility allocation in companies with complex organizational structures.

Roles [12]: A role describes a responsibility for thematically related activities with similar complexity. They can be independent of the given organizational structure of the company, i.e. an employee with a specific role can perform cross-departmental activities. The existing roles (e.g., lean manager) are therefore one way of clearly assigning the responsibilities of those involved. Therefore, this dimension was considered relevant by the experts in addition to the organizational structure. However, the roles in change management (e.g., Change Agent) or generally applicable roles such as the RASCI roles (Responsible, Accountable, Supported, Consulted and Informed) [3] are not taken into account here, since responsibility profiles can be created for these roles, but there is no added value in integrating them directly into the description schema.

Function [13]: It allows to grasp and comprehend the different activities carried out in the company, specifically in the context of production and assembly, that are affected by an MC. The execution of these tasks is defined by a set of sub-tasks, that become functions as soon as they are assigned to stakeholders. The execution dimension comprises all activities on an operative level that keep an enterprise functioning. These include activities from *assembly* [28, 15, 26], *production technologies* described and defined by DIN8580 [5], activities within *logistics* [26], *change management related activities* [12] and *change implementation activities* [6, 16]. Moreover, functions or activities carried out simultaneously by the stakeholders are considered by this dimension, for example, product development activities and quality management activities done by the same stakeholder.

Resource View [22]: By identifying the physical place in which a MC takes place, as well as the affected products and manufacturing equipment, this dimension localizes the MC. The resource view follows on the one hand an incremental view of the product starting from its separate parts all the way to its product family [23] and on the other hand, a plant hierarchy, starting from the plant and going all the way down to a single working station [25].

4. Method for stakeholder identification

The proposed stakeholder identification method was systematically developed following the four phases of software development as proposed by Kleuker [11]. First, the requirements were defined based on relevant literature and several discussions with the experts of the application partner (see Chapter 5.1). Subsequently, the rough and fine conception of the method took place in an iterative procedure that included feedback from the application partner. The final implementation took place in the form of a VBA-based tool for Microsoft Excel. The resulting method consists of three main modules: the initial collection of information to describe the distribution of responsibilities, the systematic description of MC, and the comparison of these two inputs to identify the relevant stakeholders. The initial collection of information provides the basis for the developed approach as it results in a morphological box that graphically captures the dimensions considered as relevant by the company for the description of the responsibilities of the employees. These dimensions are then used by the employees to model their responsibilities, creating individual Change Responsibility Profiles (CRP). The morphological box is again used in the second module for the systematic classification of new MC. The third module compares the characteristics of the MC against the generated CRP and determines the degree of similarity, indicating the likelihood of the person or role being a relevant stakeholder.

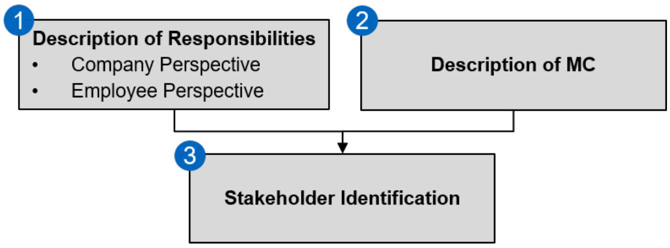

Fig. 1. Overview of the developed approach

4.1. Description of Responsibilities

This module of the method is composed of two main phases: the capturing of the company and the employee perspective. In the company perspective, the company first analyzes and chooses the change dimensions which are relevant for SI in their MCM. Afterwards, the company defines the different levels or elements pertaining to each dimension, thus setting the granularity. The selection of dimensions and granularity should be carried out during a workshop with several employees from different departments and phases of the MCM, as this ensures the necessary general overview. In addition, the reasons for the selection should be carefully documented to ensure later traceability and update-ability. The company could for example choose the dimension change costs and define its granularity with three levels: low, medium, and high costs. These granularity levels could then be complemented with a quantitative value. The output of this perspective is a morphological box containing the dimensions selected as well as the defined granularity in form of levels or elements of each dimension.

In the employee perspective, the elaborated morphological box is used to graphically represent the distribution of responsibilities. Each employee chooses the dimensions and levels which best describe their responsibilities according to the roles taken up by their position. The employees have the possibility to chose critical elements of a dimension. If these elements are affected by MC, the employee is directly identified as a relevant stakeholder. E.g. if a stakeholder wants to be contacted in all changes affecting the milling processes, he could choose this as a critical element in his CRP. Any specified combination should at least have two dimensions, otherwise, the selection is directly considered as a critical dimension and no meaningful quantification of the match between change description and CRP can take place. The main difference between this module and the other two is the frequency of execution. Since this module provides the information basis for the execution of the approach, it is carried out only once when the approach is introduced in the company. However, a change in an employee profile or in the design of the dimensions may necessitate an update. The other two modules are used for the actual SI and are therefore repeated for each new change.

4.2. Description of Manufacturing Change

In the second module, new MCs are systematically described using the dimensions specified in module 1. Thereby all dimensions and elements are selected which apply to the change. The necessary information should be collected by the change coordinator or qualified employees. However, it is important to emphasize that some of the information required for this purpose is already captured as standard in the majority of manufacturing companies. This information is the basis for the matching between the characteristics of the MC and the responsibilities of the employees, which represents the third part of the method.

4.3. Stakeholder Identification

This module addresses the matching of the responsibility profiles of the employees with the characteristics of the MC. The degree of similarity is used as a key indicator of the relevance of a stakeholder. It is calculated by dividing the number of matching elements between the change description and the responsibility profiles by the total number of selected elements of the change description. If a path containing only two elements is affected by the MC, the person is directly identified as a stakeholder. In addition, a person or role is also directly determined as a relevant stakeholder if a critical dimension he or she has selected is affected by the change. As a final result, this module provides a list of potentially relevant stakeholders sorted by the degree of match between MC and responsibility profile or the critical dimensions concerned.

5. Industrial application and evaluation

The evaluation of the method was carried out at a globally acting German mechanical engineering company. Inspired by the Design Research Methodology, it is divided into an application evaluation and a success evaluation. The application evaluation focuses on the assessment of whether and how well the method was applicable in the case under consideration. The success evaluation, on the other hand, assesses the quality of the results and checks whether they help to solve the originally addressed problem.

5.1. *Description of Responsibilities*

The initial collection of information took place in the course of three interviews with leading executives from the areas of production engineering, manufacturing development, and work preparation. The total time required was about 3 hours, with a major part of the time spent on information gathering. Ten change dimensions were selected as relevant for the identification of stakeholders, including affected production process and change risks. These dimensions were then expanded to include corresponding categories. For example, for "Change Risk," the levels "low," "medium," and "high" were added. Fifteen employee CRP were obtained, and it was separately indicated in which cases which RASCI role was relevant. The employees also had the option of specifying critical dimensions and two-level links between dimensions (e.g. affected production process: milling AND change costs: high). The profiles were collected in individual interviews that lasted about 20 minutes. Figure 2 shows an exemplary CRP.

5.2. *Evaluation*

The method was applied to five actual change scenarios. The first scenario involved the installation of an articulated arm robot to replace multiple manufacturing stations. In the second scenario, an existing production technology (poking) is to be replaced by roller peeling. In the third scenario, a new production line is integrated into an existing plant. In the fourth scenario, the implementation of a new product variant is addressed, and in the fifth scenario, the modernization of an assembly line takes place. For all application scenarios, expert employees conducted a change classification according to the defined dimensions and elements which took about five minutes per scenario. A systematic comparison with the CRP was used to determine the potentially affected employees and roles. Figure 3 shows the result for use case 5. The figure contains the degree of fit between the RASCI roles and the different employees, named with the department and employee number (e.g. Quality 1). For example, the employee "Process 1" was considered relevant for the role "Responsible", since the change affects a critical dimension of his CRP.
The success evaluation and application evaluation were carried out within the framework of eight expert interviews, in each case, the results of all five application cases were discussed. The interviewees then rated 14 statements in a questionnaire on a Likert scale of 1-5, where 1 means "Strongly agree" and 5 means "Strongly disagree". For better interpretability of the obtained results, the statistical ratios mean (μ) and standard deviation (σ) are given below. A selection of the most important statements is presented in Figure 4.

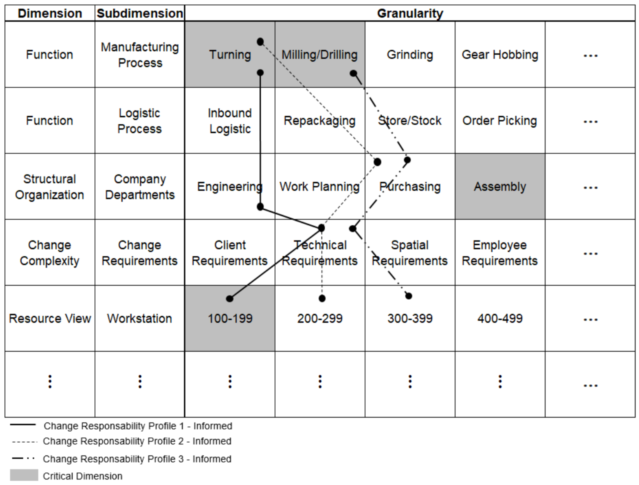

Fig. 2. Excerpt of an exemplary CRP

Responsible	Fit	Support	Fit	Consulted	Fit	Informed	Fit
Process 1	CD	Process 1	CD	Process 1	CD	Planing 2	CD
Controlling 1	CD	Process 2	CD	Controlling 1	CD	Production 2	CD
Quality 1	CD	Manufacture	CD	Planing 1	CD	Process 1	CD
Production 4	60%	Assembly	CD	Logistic 1	CD	Production 4	CD
Production 1	45%	Planing 1	40%	Production 4	20%	Controlling 1	CD
Quality 1	40%	Quality 3	35%	Process 1	14%	Planing 1	35%
Process 2	20%	Quality 2	25%	Production 3	10%	Production 3	30%
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

CD: Critical Dimension

Fig. 3. Results of use case 5

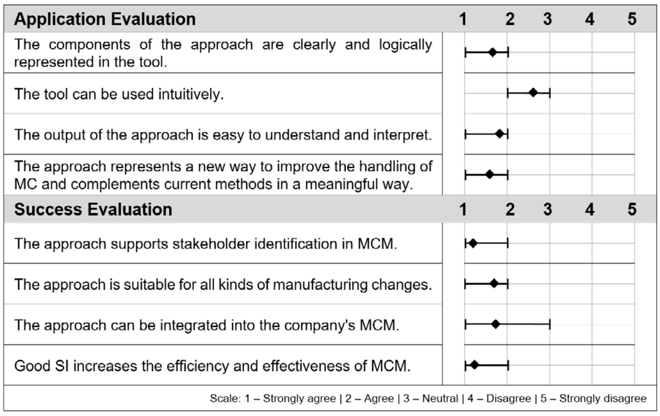

Fig. 4. Evaluation of the developed approach

In the application evaluation, the logical structure of the implemented tool (μ = 1.6, σ = 0.5) and the ease of interpretation (μ = 1.9, σ = 0.6) were confirmed. In addition, the participants agreed that the method usefully complements existing change management methods (μ = 1.6, SD = 0.5). In contrast, the intuitive usability significantly was rated worse (μ = 2.6, σ = 0.5), which can be explained by the prototypical implementation state. Regarding the evaluation of the benefits, the two main objectives of the approach were evaluated positively. According to the respondents, the method supports the SI in MCM

This is a resupply of March 2023 as the template used in the publication of the original article contained errors. The content of the article has remained unaffected.

(μ = 1.25, σ = 0.46) and thus enables a more effective handling of MC (μ = 1.25, σ = 0.46). The ability to integrate the approach into the existing change management process was also viewed positively (μ = 1.75, σ = 1.0). In contrast, the input of the information by a single person was criticized (μ = 3.1, σ = 0.6), since a single person often does not have the necessary understanding of the MC.

6. Conclusion

In this paper, we present an approach that supports the identification of stakeholders in MCM. It is based on a matching between the responsibilities of the employees and a systematic description of new changes. The output is a statement about potentially relevant employees and roles. The approach was applied and positively evaluated in collaboration with a German mechanical engineering company in five application scenarios. Potential for improvement was identified in the change description, as this is often difficult for a single person to complete correctly. This should be taken as a motivation for future work to develop a systematic support for change characterization. Historical change data could be considered as a source of information [23]. The collection of additional responsibility profiles and a broader application in industrial practice could be used to generate a better understanding of optimization potentials and the cost-effectiveness. Cross-plant use cases should also be considered to obtain more precise statements about the limitations.

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