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Knowledge management framework for complaint knowledge transfer to product development

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Abstract

The paper presents a methodological framework based on the analytical network process (ANP) approach for selecting knowledge management (KM) solutions for complaint knowledge transfer to product development. Existing approaches to technical complaint management (TCM) mostly neglect the necessity of knowledge transfer, and thus do not address quality or sustainability issues. The framework addresses this shortcoming by providing a systematic approach for selecting appropriate KM solutions in a given organizational environment. Based on extensive literature review competing objectives, diverse criteria as well as various organization specific factors have been identified and integrated into the framework. An expert study amongst 15 KM experts was conducted for parametrizing the model (i.e., to evaluate KM solutions with respect to the identified objectives and criteria). The framework enables long-term effects on failure-based learning and facilitates the design of a more sustainable TCM.

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Keywords: knowledge management; learning organization; technical complaint mangement; sustainable product development; ANP; MCDM

1. Introduction

These days, manufacturing companies are subject to a market environment that is characterized by constantly increasing customer requirements at shorter product life cycles [1]. In order to meet global competition with regard to these challenges, companies need to design and deliver products both providing significant value to their customers and being sustainable [2]. Herewith, the ability of customer-oriented product development at minimal time becomes a key success factor. Additionally, the consideration of sustainability aspects in the product development process is of

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increasing importance as customers' demands for sustainable products are rising [3]. Product development particularly allows addressing these aspects upfront the product life cycle [4]. In this context, technical complaint management (TCM) has repeatedly proposed to be a source of knowledge for identifying and addressing critical aspects to product quality and sustainability [5]. TCM comprehends all technical related efforts to solve criticized product failures underlying internal or external complaints. It aims at fast failure identification, immediate root cause clarification and long-term prevention of reoccurrence whilst considering the entire product life cycle. Although research indicates great potential, long-term effects of failure-based learning lag behind [6,7]. In order to address this shortcoming, a conceptual process model for complaint knowledge transfer was developed in former research by LINDER ET AL. [8] The focus of this paper is to consider this model in detail by integrating a framework of knowledge management (KM) solutions and a corresponding selection approach using the analytical network process (ANP).

The paper is organized as follows. First, the state of the art of knowledge management in TCM research is briefly reviewed. Afterwards, a literature-based framework of KM solutions is developed, which serves as methodological support for the above mentioned process model. Finally, an ANP model for the evaluation of the identified solutions is derived and parametrized based on the results of a study amongst 15 KM experts.

2. Knowledge management in technical complaint management research

This chapter provides an overview of relevant research works related to aspects of knowledge management within technical complaint management. Specific TCM reference models or processes can be found in different fields and vary greatly in terminology (e.g., CHIEW and WANG [9], GOLDSZMIDT ET. AL. [10], KLAMMA ET AL. [11], SCHMITT and PFEIFFER [12], BEAUJEAN [13], BOSCH and ENRIQUEZ [14]). Although, these models agree on similar process steps to guide failure correction, the necessity of transferring complaint and failure knowledge is neglected [8].

Instead, prior research mainly incorporates approaches for description and standardization of complaint information and knowledge. ORENDI [15] presents an approach for complaint and failure classification based on quantitative, qualitative and verbal descriptions. LASCHET [16] describes an alphanumeric and mainly cost-oriented concept for complaint classification. EBNER [17] proposes a concept that allows the use of field failure data as standardized descriptions in the phase of product development. FUNDIN and ELG [18] address the use of dissatisfaction feedback for continuous learning in product development. The expert-based method by PLACH [19] (research project FAMOS) allows a computer-aided failure management by using text-based descriptions of failures with exclusive syntax. Additionally, industry-specific approaches can be found in scientific literature. KIRATLI [20] developed a relative classification of failures at the example of cutting manufacturing facilities. HORNAUER [21] provides a catalog, which is used for classification of failure types and causes in the field of sheet metal forming. RUETTHARD [22] focuses on the feedback of experience in the stages of product planning at the example of complex sheet metal parts.

The presented approaches give an overview regarding the integration of KM aspects in TCM. However, theoretical prototypes that specify the long-term transfer of complaint information and knowledge are practically non-existent or have no application in practice. In order to extend the scope of existing models to a more sustainable TCM, it requires a specific approach to generate, distribute and use complaint knowledge in the long run. Hereof, the concept developed by LINDER ET AL. [8] serves as basis for further considerations in the following sections.

3. Long-term complaint knowledge transfer to product development

3.1. Conceptual process model

The conceptual process model for long-term knowledge transfer [8] builds on generic KM activities defined by PROBST ET AL. [23]: Identification, acquisition, development, distribution, usage and protection of knowledge. LINDER ET AL. [8] have applied these activities to the objective of long-term complaint knowledge transfer. They suggest to conduct knowledge identification, acquisition and development as well as distribution and usage with the inputs of the previous TCM phases (i.e. *data organization*, *failure identification* and *failure correction*). Hence, the model includes three modules, namely *acquisition*, *analysis* as well as *distribution and usage*.

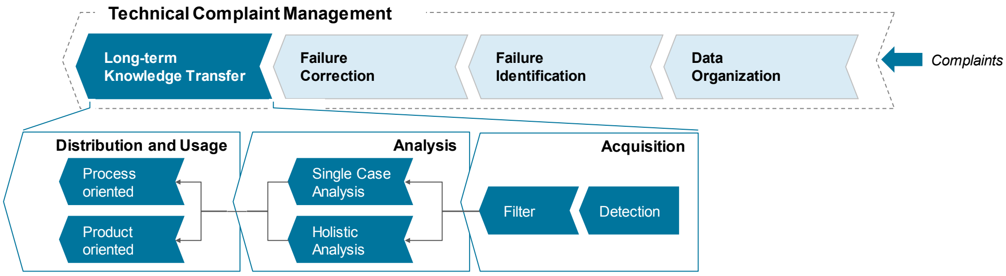

Fig. 1. Conceptual process model for the long-term complaint knowledge transfer to product development [8]

The aim of the *acquisition module* is to detect all relevant complaint information to create a comprehensive information basis. Input to this process step is information about relevant failure details underlying the complaint (e.g., initial failure event and information from root cause analysis). Further, the information is filtered as not all complaint information tend to be relevant for usage in product development. Within the *analysis module* it is distinguished between single case and holistic analysis [24]. Single case analysis focuses on the analysis of specific complaint information, whereas holistic analysis involves the comprehensive complaint information of an organization. The outputs of this process step are analysis sets, which contain recognizable failure patterns and long-term measures for failure elimination. These sets are further processed in the *distribution and usage module*. This module's objective is the transfer of developed complaint knowledge (i.e., enriched complaint information) to future product developments. Upon usage of knowledge, it can be distinguished between product- and process-oriented use [25]. In both cases, measures from the analysis phase are transferred to the development documentation.

Under consideration of the modules' characteristics, it was found that a uniform and general flow-chart for the use of complaint information would not be expedient. Instead, the process depends on individual requirements, organizational characteristics as well as diverse dimensions (e.g., quality, time, sustainability). In order to specifically design and effectively perform the process, a targeted methodological support for selecting appropriate KM solutions is necessary. Therefore, a general solution framework was developed. It is outlined in the following section.

3.2. KM solution framework

An extensive range of methods and tools is applicable to the implementation of the strategy outlined in the previous section [26]. Traditional KM methods, for instance, are a suitable option as they aim at supporting and facilitating the flow of knowledge within organizations [27]. Additionally, data-oriented KM systems (i.e., systematic approaches to manage organizational knowledge through information and communication technology (ICT) [28]) as well as quality management methods can be applied to support the underlying strategy.

There are numerous scientific contributions presenting different approaches to systemize KM solutions (e.g., by process-orientation [29,30,31,32] or (non-)technology group [33]). The most widely used typology refers to the model of PROBST ET AL. [23] mentioned in section 3.1. Building on this typology, the most common methods, tools and systems have been extracted from scientific literature and categorized according to their essential functions. The resulting framework consists of six higher-level categories and 18 more specific KM solutions (see Fig. 2):

- *Lessons learned and best practices* are designed to systematically collect, evaluate, and consolidate experiences, developments, failures as well as risks [27,34]. The consideration of documented practical knowledge can be incorporated in future product development projects [35].
- *Knowledge communities* pursue the extension and improvement of organizational members' capabilities and knowledge [27]. Moreover, solutions assigned to this category aim at a centralized development and distribution of personal knowledge [36].
- *Education and training* aims at the application and targeted advancement of organizational knowledge with the help of electronic and digital tools considering various learning methods [37].
- *Expert search and investigation* provide structures and platforms, which enable the identification of experts or other knowledge carriers within an organization and the transparent visualization of available knowledge [38].

- *(Un-)controlled interaction opportunity* refers to real or virtual areas in an organization where employees talk informally allowing knowledge to flow [39].
- *Information transfer and allocation* solutions mostly refer to digital platforms, so called web 2.0 technologies, for generating, sharing and refining information [40]. These allow extraction and reuse of data, information and knowledge in a flexible way across the organization [41].

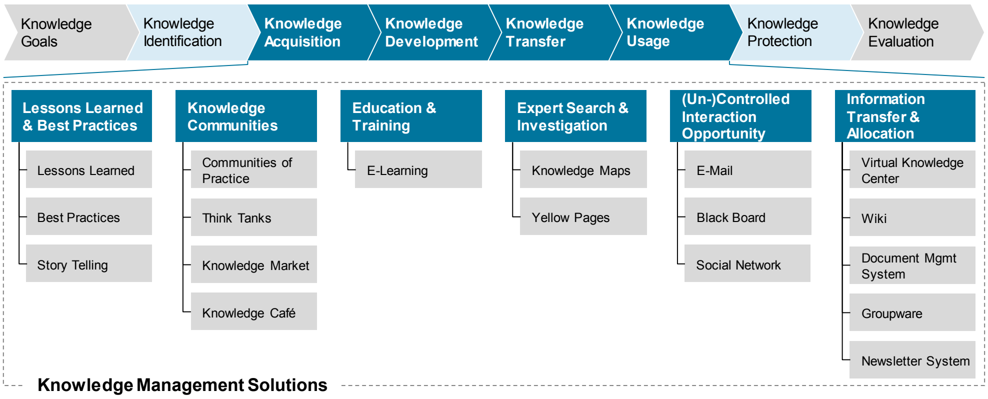

Fig. 2. Systematic classification of KM solutions (methods, tools and ICT systems).

Although there is research about how to perform knowledge management, few contributions suggest which KM solutions should be applied to effectively implement a certain strategy. The selection of appropriate KM solutions depends on the desired objective, resources as well as company specific preferences. Hence, the selection process is characterized as a multi-criteria decision-making problem (MCDM) [42], which might be solved by applying ANP.

4. Analytical network process model for selecting knowledge management solutions

The proposed framework builds on the assumption that a targeted application of KM solutions is beneficial to transfer complaint information and knowledge to product development. However, selecting and applying the most suitable solutions is crucial to the effectiveness and efficiency of this process. For this reason, an ANP based model for selecting KM solutions from the developed framework has been developed and parametrized. The methodological approach, the development and the parametrization of the model are presented in the following sections.

4.1. Analytical network process

The analytical network process is a generalization of the analytical hierarchy process (AHP) developed by SAATY [43,44]. Both methods are designed to support rational and unbiased decision-making in complex problem settings characterized by having more than one criterion [45]. The application of AHP or ANP includes a breakdown of complex problems into individual elements (i.e., goals, decision criteria and alternatives). This enables decision-makers to conduct a series of pairwise comparisons of elements, and hence prioritize them.

The AHP structures a decision problem hierarchically in terms of its elements. However, this structure does not consider interactions, dependencies and feedback between higher and lower level elements. If decision-making problems involve elements that are believed to be internally dependent, it is recommended to use the ANP approach [46]. ANP extends the AHP to decision-making problems with dependency both within a cluster and among different clusters. Thus, ANP replaces the hierarchical structure with a network structure to represent such complex systems.

4.2. Development of the analytical network process model

According to SAATY and VARGAS [47] the ANP method is composed of four main steps: *(i)* Model construction and problem structuring; *(ii)* Pairwise comparison matrices and priority vector; *(iii)* Formation of the supermatrix; *(iv)* Selection of the best alternatives or weighting attributes. This procedure is presented hereinafter for this paper.

4.2.1. Model construction

Goals. The overall goal associated with the strategy presented in section 3.1 requires further elaboration. For this purpose, sub-goals are defined in accordance with the modules of the conceptual process model for the long-term knowledge transfer: *Acquisition* (G_1), *analysis* (G_2), *distribution and usage* (G_3).

Criteria cluster and criteria. In order to formulate the ANP model, it is necessary to identify clusters of criteria that influence the choice of specific KM solutions. The criteria for the proposed model were selected on basis of literature as well as suggestions of KM experts. In total, four essential clusters of criteria appear to be relevant:

- *Functionality and features* (C_1) refer to characteristics, which are covered by a KM solution. Moreover, this cluster considers how well a solution can meet the specific requirements of an organization. As such, three key functional elements have been identified: Communication (S_1), documentation (S_2) and reporting (S_3). Communication refers to the feature provided by a KM solution that helps users to work together and share knowledge [48]. This should include all forms of interaction. Documentation describes the function of embedding knowledge in documents involving storage, publishing, re-use and searching [49]. Reporting refers to information processes that allow controlling and monitoring the behavior of users in sharing and transferring the knowledge base [50].
- *Business application* (C_2) is the degree of fit that a solution has to an organization's (changing) landscape. For instance, a KM solution that works well for medium-sized organizations might not perform as well if it is implemented in larger corporations. The cluster consists of the criteria integrability (S_4), scalability (S_5) and standardizability (S_6). Integrability describes the ability to integrate a KM solution in existing organizational structures or systems. Scalability refers to the ability to scale up without performance losses if the number of knowledge users increases [51]. Standardizability describes the degree of standardization in the workflow when using a certain KM solution.
- Another common factor for influencing the choice of KM solutions are *costs* (C_3) or more generally, the economic perspective. According to the generally accepted accounting principles (GAAP), costs can be grouped under capital expenditure (S_7) and operating expenditure (S_8) [28]. Capital expenses are non-recurring costs (e.g., infrastructure, hardware, software), while operating expenses are recurring (e.g., maintenance, trainings, software subscriptions).
- *Efforts* (C_4) refer to time-based characteristics of alternatives. This includes processing effort (S_9) (i.e., time effort in day-to-day use of a solution) and training effort (S_{10}) (i.e., training time to learn a method or ICT tool) [52].

Alternatives. The six categories of KM solutions from the framework presented in section 3.2 represent the possible alternatives in the choice of the most suitable KM solution: *Lessons learned and best practices* (A_1), *knowledge communities* (A_2), *education and training* (A_3), *expert search and investigation* (A_4), *(un-)controlled interaction opportunity* (A_5), *information transfer and allocation* (A_6). They form the alternatives cluster.

Final ANP model. The developed ANP model for company specific selection of KM solutions from the proposed framework is shown in Figure 3.

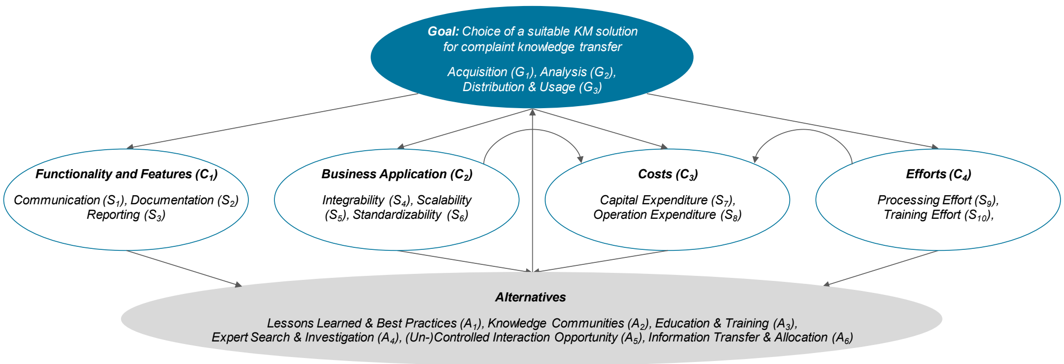

Fig. 3. Final ANP model for selecting KM solutions

4.2.2. Pairwise comparisons and formation of the supermatrix

Both ANP and AHP have been successfully applied in the field of knowledge management and KM tool selection (e.g., WU and LEE [42], NGAI and CHAN [53], GRIMALDI and RIPPA [54], GRECO ET AL. [28]). However, one of the criticism of these methods is related to the amount of judgements necessary for its application [55]. In order to reduce this number for use in practice the model is parametrized on basis of expert judgements. For this purpose experts have conducted pairwise comparisons of decision elements at each cluster in terms of their control criteria

Methodology. A quantitative survey-based study was conducted to overcome the above mentioned shortcoming of the ANP approach. In total, 15 experts from academia and industry participated in this study. Prerequisite for the participation in the study were at least two years of practical experience in conducting knowledge management projects and using KM solutions. The survey was conducted in form of a structured questionnaire, which contained pairwise comparison matrices to evaluate the alternatives with respect to goals and criteria of every cluster. To do this, elements were compared using nine-point ratio scales (i.e., equal, moderate, strong, very strong and extreme as verbal equivalents) as suggest by SAATY [44]. For detailed information on the conduction of the expert study (e.g., questionnaire and items included), please contact the corresponding author. The developed model was implemented in the software super decisions (version 2.8.0), which allows to easily generate pairwise comparison matrices of a given model. In this way, weights of goals and criteria have been calculated and used for initial parametrization.

Results. The results of the pairwise comparisons were aggregated using the geometric mean method. In a further step, the aggregated values have been used to derive overall priorities of the alternatives, which are represented by the unweighted supermatrix W [44]. Hereby, W is partitioned and composed of a set of relations between clusters (i.e., local priorities derived through pairwise comparisons; ranging from 0 to 1). Particularly, pairwise comparisons of the goals with respect to alternatives as well as alternatives with respect to criteria were conducted. The average results can be found in submatrices W_A and W_C of the unweighted supermatrix W and are presented in Figure 4. Submatrix W_A contains the weights of alternatives with respect to sub-criteria, whilst W_C denotes the weights of goals with respect to the alternatives. As the values of matrices W_A and W_C generally map the alternatives with the criteria and goals of the underlying decision model, they are independent from company-specific preferences. Consequently, these matrices will be held constant for any use case.

	G_1	G_2	G_3	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	A_1	A_2	A_3	A_4	A_5	A_6
G_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27056	0.08361	0.15125	0.63010	0.31081	0.33131
G_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08522	0.47211	0.09051	0.15146	0.49339	0.28943
G_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.64422	0.44427	0.75825	0.21844	0.19580	0.37926
S_1														0	0	0	0	0	0
S_2														0	0	0	0	0	0
S_3														0	0	0	0	0	0
S_4														0	0	0	0	0	0
S_5														0	0	0	0	0	0
S_6		W_S							W_D					0	0	0	0	0	0
S_7														0	0	0	0	0	0
S_8														0	0	0	0	0	0
S_9														0	0	0	0	0	0
S_{10}														0	0	0	0	0	0
A_1	0	0	0	0.04303	0.37394	0.37080	0.17404	0.12590	0.18081	0.15111	0.14674	0.16433	0.10629	0	0	0	0	0	0
A_2	0	0	0	0.44137	0.03115	0.08398	0.18065	0.08996	0.02655	0.19261	0.12643	0.15357	0.17249	0	0	0	0	0	0
A_3	0	0	0	0.07943	0.14988	0.16991	0.06665	0.02800	0.14450	0.03113	0.16989	0.11125	0.15235	0	0	0	0	0	0
A_4	0	0	0	0.06958	0.08417	0.07661	0.10157	0.09003	0.40351	0.03969	0.15496	0.23830	0.04940	0	0	0	0	0	0
A_5	0	0	0	0.21129	0.02732	0.08180	0.43109	0.45172	0.03128	0.52819	0.29239	0.07659	0.48934	0	0	0	0	0	0
A_6	0	0	0	0.15531	0.33354	0.21690	0.04600	0.21440	0.21336	0.05727	0.10960	0.25595	0.03013	0	0	0	0	0	0

W_A W_C

Fig. 4. Matrix W_C and W_A of the unweighted supermatrix (average results of expert study, n = 15)

Several universal implications for the selection of KM solutions, and thus the design of the process model can be derived based on the results from Figure 4. The values of submatrix W_A indicate the most favorable alternative for each single criterion. For instance, KM solutions from group knowledge communities *(A_2)* are favorable with respect to the criterion communication *(S_1)* at 0.44137. Through matrix W_C, each KM solution emphasizes its own specific goal. Thus, W_C indicates which alternative should be preferably applied to the different modules. For the acquisition module *(G_1)* the most relevant alternatives are expert search and investigation *(A_4)* at 0.63010 as well as information transfer and allocation *(A_6)* at 0.33131. KM solutions A_5 and A_2 cast highlight at analysis module *(G_2)* at 0.49339 and 0.47211 respectively. For distribution and usage *(G_3)* KM solutions A_3 at 0.75825 and A_1 at 0.64422 are most feasible.

4.2.3. Selection of the most suitable KM solution

As stressed before, the obtained results only reflect the local priorities. In order to select optimal KM solutions, the model still requires the conduction of pairwise comparisons in order to derive matrix W_S, which represents the weights of criteria with respect to different goals. Additionally, pairwise comparisons for matrix W_D have to be conducted to denote the inner dependencies of criteria. However, these evaluations have to be carried out organization-specific.

5. Conclusion

In this paper, an ANP-based KM solutions framework for the long-term complaint knowledge transfer has been presented. A detailed problem statement and literature review pointed out the necessity to extend the scope of existing technical complaint management models to a more sustainable approach for long-term knowledge transfer.

The presented findings are new in the field of technical complaint management. The main contribution is a systematic framework using the analytical network process approach to select appropriate knowledge management solutions along the process of long-term complaint knowledge transfer. The outcomes of the proposed framework are ranking scores that show practitioners the contribution of KM solutions to the knowledge transfer process. The results from an expert-based parametrization of the framework give first indication of alternatives that need to be emphasized with regard to the different phases of the knowledge transfer process as well as specific selection criteria.

To sum up, the proposed KM solutions framework helps to handle several complex factors in an objective and logical manner. However, company-specific preferences have to be considered to derive a comprehensive ranking of KM solutions. Case studies in the German manufacturing industry are planned to test the framework and its practical implications. Specifically, its usefulness and contribution to solve quality and sustainability issues by transferring appropriate complaint knowledge needs confirmation by broader data collection. Moreover, the case studies will be used to developed general profiles within the proposed framework. These profiles should suggest KM solutions considering general organizational prototypes (e.g., by number of employees, industry or organizational structure).

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