HYBRID MULTI-CRITERIA DECISION MAKING MODEL FOR CUSTOMER KNOWLEDGE MANAGEMENT IN SOFTWARE INDUSTRY

TIBOR KRENICKY[1], MORTEZA RAJABZADEH[2], ARASH KHOSRAVI[2], VILIAM ZALOGA[3], TADEUSZ ZABOROWSKI[4]

[1] Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Slovakia

[2] Mahallat Institute of Higher Education, Faculty of Engineering, Mahallat, Iran

[3] Sumy State University, Faculty of Technical Systems and Energy Efficient Technologies, Sumy, Ukraine

[4] Polish Academy of Sciences, Poznan, Poland

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e-mail: tibor.krenicky@tuke.sk

In this study, the enablers of Customer Knowledge Management (CKM) software companies are investigated. Consequently, the conceptual CKM enabler model is developed by extracting "organizational", "technological" and "human" factors from the literature. Then, a Multi-Criteria Decision-Making (MCDM) approach is applied to identify the dependence relationships of factors by using the Analytic Network Processes (ANP) and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) techniques. The inter-dependencies significance among the factors is evaluated by DEMATEL. ANP technique is used in order to clarify the relative significance of the factors and identify the weight and priority. The results show that the "organization" dimension is the most considerable aspect of enhancing CKM in software development. The "organization" aspect has more interaction with other aspects and activates the "technology" and "human" factors. In addition, "technology" is the second dimension that influences "human" and "organization". Due to the importance of CKM for organizations, this research provides a significant contribution in the context of CKM by extracting and ranking the CKM antecedent factors for enterprise software development context.

KEYWORDS

qualimetry, knowledge management, risk of low quality, summarizing indicator, multicriteria quality assessment, dimensionless scale.

1. INTRODUCTION

Many previous research studies in software quality enhancement have focused only on technical aspects of software quality [Macala 2009, Cho 2013, Panda 2014, Kurdel 2015a,b, Schaarschmidt 2015, Valicek 2016 and 2017, Macala 2017, Hogarth 2018, Zaloga 2019 and 2020, Muniz 2020]. However, the nature of enterprise software depends on organizational facilitators, such as transferring and integration of customer knowledge [Panda 2013, Hovorun 2017, Chaithanapat 2021]. Therefore, there is a need to investigate organizational factors such as CKM that enhance software quality. The research was conducted by Trishch and Panda [Panda 2019, Trishch 2021] and Sankaran [Sankaran 2018] to investigate organizational factors that affect software quality. They highlighted the role of the transfer and integration of customer knowledge, but did not explore how could be applied CKM successfully in the software companies, thereby leading to improved software quality. Akbar et al. [Akbar 2021] emphasized how Knowledge Management (KM) impacts different aspects of software quality in offshore development projects. They underscored the function of customer knowledge transfer and assimilation for improvement of software quality [Zaborowski 2007, Mrkvica 2012, Michalik 2014, Baron 2016, Olejarova 2017, Chaus 2018, Murcinkova 2017, Vagaska 2017 and 2021, Straka 2018a,b, Frey 2019, Modrak 2019, Zaloga 2019]. According to Benabdellah, Pandova & Panda [Panda 2016 and 2021, Pandova 2018, Benabdellah 2019] and Montgomery [Montgomery 2018], key customer knowledge faces the risk of not reaching the intended software engineers.

In this study, an empirical study was conducted to investigate possible factors influencing CKM in the software development companies. The questions that have been fostered for this research are: (a) What are the antecedent factors that impact CKM in organizations based on "organization", "human", and "technology" framework? (b) What theoretical model is appropriate to be used to enable the CKM in the software development companies? and (c) What framework is appropriate to rank the antecedent factors for the software development companies by using MCDM technique?

The presented research has two aims. First, due to the lack of a theoretical solution for CKM in the context of software development [Dyadyura 2017a,b, Lakshman 2021], this investigation involves an assessment of the degree of significance in relation to interdependency among the crucial factors for CKM. Second, this study recommends a MCDM framework to determine the significance of the established factors for CKM in the area of software development. This MCDM model includes two components, the ANP and the DEMATEL. The purpose of the DEMATEL is to fabricate interconnections among the integrated model's adoption factors. This facilitates an examination of the degree of interdependency among the precursor factors. Subsequently, the ANP was brought into the equation to: (a) Ascertain the comparative significance of the precursor factors, and (b) Examine the means by which specialists in the field of software development assess and arrange the key factors in their order of priority. It should be noted that these specialists are wholly familiar with CKM in the software development processes.

2. LITERATURE REVIEW

Levy et al. [Levy 2019] conducted a survey in different industries and found that improved product quality is one of the important outcomes of CKM. Product and service quality is discussed as part of performance outcome of CKM. Constant interaction with consumers and attaining customer knowledge are vital aspects for meeting their requirements and enhancing product quality. Enhancements in the degree of understanding of consumers and their needs drive improvements in the product/service quality, as well as inventive customization or designing of new inventive products that symbolize the requirements and demands of consumers [Pogrebjak 2016, Gu 2017, Kim 2019]. According to Kim [Kim 2020], the attainment of customer knowledge has a

positive relation with the performance of products. The “Generic CKM Model” discussed in the [Sukhodub 2018, Stormi 2020] demonstrated that product quality is one of the outcomes of CKM. Thus, from the perspective of enterprise software development, we emphasize on the CKM model for improving software quality. Several definitions of Software Quality (SQ) are used, which generally concur on what is the meaning of quality, and it can be outlined by the term “satisfaction of consumer’s needs” [Waqas 2021]. This study examined the CKM precursor factor for enhancing the CKM which is lead to the software product quality. In the following section, we formulate a conceptual model on the basis of the CKM enablers extracted.

3. RESEARCH METHODOLOGY

The main function of research methodology is explaining how to answer the research questions [Morgan 2020, Zare 2020, Bozkurt 2021]. In the first phase of the research design framework, the problem and objectives of this study were defined and, accordingly, the related theoretical foundation was reviewed. In the second phase, the result of the study by Khosravi [Khosravi 2017] was used. They have conducted the comprehensive systematic literature review and extracted 22 CKM enabler factors from 66 papers on seven databases. Based on the extracted antecedent factors, the conceptual model was proposed. After that, the experts in the software development domain ranked the extracted factors by using a hybrid MCDM method. Finally, in this phase the final CKM theoretical model for software development companies was developed.
Fig. 1 offers an outline of the procedure employed for analyzing the conceptual model by using hybrid MCDM method. This procedure, which entails the utilization of the DEMATEL and ANP techniques, includes two main phases.

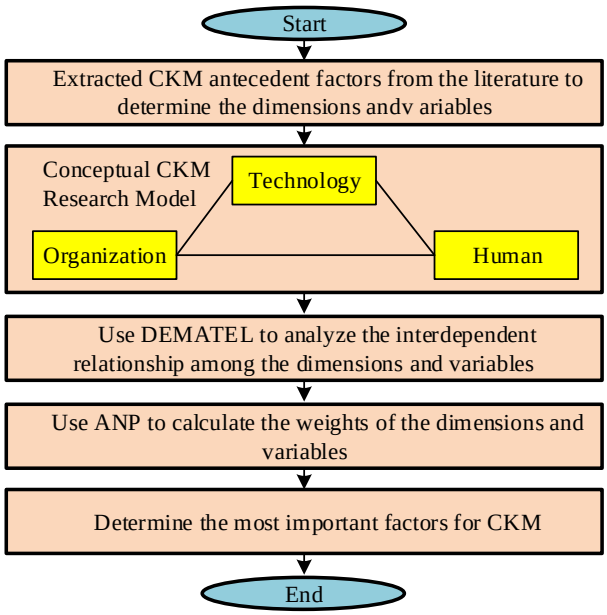

Figure 1. Research flow for hybrid MCDM model

The initial phase entails the employment of the DEMATEL to reveal the link between the main factors (dimensions) and sub-factors (variables), as well as to scrutinize their interdependency. As the determination of the link between the dimensions and variables is crucial for an accurate establishment of their weights, the DEMATEL process is deemed more appropriate than conventional procedures for this purpose. This is attributed to the decision-making superiority of the DEMATEL process in terms of investigating the interdependency among constituents of a network for real-world applications. The application of the DEMATEL process is followed by that of the ANP, which serves to grade the factors in each group in order to unveil those of higher priority.

4. CONCEPTUAL CKM RESEARCH MODEL

In this research, based on systematic literature review which conducted by Khosravi [Khosravi 2017], CKM antecedent factors were selected. 66 articles concerning to CKM enablers were reviewed, and 22 antecedent factors have been extracted. According to the theory of technology [Harb 2020] and the definition of each category proposed by Van Den Brink [Astakhova 2020], the factors were categorized as “human”, “organizational” and “technological” [LaToza 2020]. According to conducted analysis, antecedent factors such as “CRM Technology Infrastructure”, “Collaboration System”, “Customer-Centric Organizational Culture”, “Individual Competences and Skills” and “CKM Strategy Development” are most iterative in the CKM literature. However, “Provide Privacy for Customers”, “Knowledge Map”, “Program Champion” as well as "Respect for Intellectual Property" are less iterative in the literature.

5. PROFILE OF RESPONDENTS

The present study focuses on the software companies that produce enterprise software such as CRM, “Accounting Systems” and “Enterprise Resource Planning (ERP)” software. The respondents in this study (Chief Customer Officer, Chief Commercial Officer, Chief Product Officer, and Chief Executive Officer) are involved in decision-making and handling the customer inquiries. These respondents are highly knowledgeable about the management of customer knowledge and product quality. The data were collected from 30 experts holding managerial positions in software development departments. These experts are well-informed on matters related to CKM. The preference for a small sample size for this study is in line with the approach of many researchers who employ hybrid MCDM techniques such as ANP with DAMATEL. When it comes to MCDM procedures, no guidelines exist for deciding the number of respondents. As ANP-DAMATEL is not based on statistics, a modest sample size was adequate [Palomares 2017, Vuori 2020]. In the opinion of Ar and Kurtaran , MCDM such as DAMATEL, ANP and AHP (Analytic Hierarchical Process) are scientifically applicable and do not require a large sample size. In the study [Khosravi 2017], MCDM procedures were used to rank factors based on the viewpoint of 12 experts. Taking these views into consideration, this study decided to use 30 specialists for the data gathering stage. Two sets of survey questionnaires were distributed among 30 ES experts from 3 different companies. The first sets of survey questionnaires were used four-point scale for analysing the interdependent relationship among the dimensions and variables (DAMATEL). The second sets of survey questionnaires used the nine-point Saaty scale for rating the

significance level of one component over another (ANP) [Zhou 2017]. In this study, the researcher considers some criteria before choosing appropriate experts. First, the experts should have enough expertise in the field of enterprise software development. Second, they should have enough knowledge regarding CKM and software quality. The definitions of the CKM enablers were provided for experts to decrease the risk of misunderstanding [Bjarnason 2022]. The same experts participated in two surveys. The majority of respondents (40%) had more than 21 years working experience in the field of software development. The majority of them were male (87%) and hold Bachelor degrees (53 %). An overview of demographic characteristics is given in Table 1.

Table 1. Sample characteristics

Respondent		Frequency	Percentage (%)
Age	25-30	6	20
	31-40	14	47
	Above 40	10	33
Gender	Female	4	13
	Male	26	87
Level of education	Bachelor's	16	53
	Master's	12	40
	Higher	2	7
Roles of respondents	Chief Executive Officers	4	13
	Chief commercial Officers	12	40
	Chief Customer Officer	8	27
	Chief product officer	6	20
Responding executives' seniority in software development	Above 21 years	12	40
	16-20 years	8	27
	11-15 years	4	13
	5-10 years	6	20

6. DEMATEL ANALYSIS

During the initial segment of the survey, 30 specialists were queried on the degree to which they consider any of the factors (dimensions as well as variables) affect each other. Their responses were required to be registered on a scale ranging between 0 and 4. DEMATEL is employed to calculate the causal level in order to facilitate an investigation into the structural connections between the three dimensions in CKM. The level of influence that the specialists consider each dimension has on the other dimensions led to the computation of the relation/influence matrix. The viewpoints of each specialist on the influence factors were entered into answer matrices, and subsequently, the preliminary direct relation matrix for the joint score of the specialists was computed. As exhibited in Table 2, the total relation matrix was constructed for the integration of the indirect influences. The computation for this construction derives from the regularized direct relation matrix.

Table 2. The total-relation matrix T for dimensions

Dimensions	Organization	Technology	Human
Organization	0.18	0.59	0.86
Technology	0.35	0.18	0.68
Human	0.02	0.03	0.02

Table 3 displays these values in three dimensions, wherein the net effect of i is expressed as (ri - ci), while the effect that dimension i contributes to the system is expressed as (ri + ci).

Table 3. Total effects and net effects for each dimension

Code	Dimensions	r	c	ri + ci	ri – ci
D1	Organization	1.62	0.55	2.17	1.07
D2	Technology	1.21	0.79	2.00	0.42
D3	Human	0.07	1.56	1.63	-1.49

The vertical vector (r + c) denotes the impact of the model in the system. Put plainly, the level of interaction between a factor and other factors in the system rises in tandem with the value of r + c. Accordingly, while the "organization" and "technology" factors were observed to have an elevated degree of interaction with other factors, the "human" variable was found to have the least degree of interaction with other variables. As portrayed in Table 5, the inclusion of the row and column vector of "organization" (r + c = 2.17) led to an unrivalled level. This circumstance is an indication that the common impacts of "organization" and other dimensions are of the highest degree. The strength of each vector's effect is revealed through the horizontal vector (r - c). For the most part, the variable is deemed causal if (r - c) is positive, while it is deemed effective if (r - c) is negative. Additionally, the net effect relationship of the total effect matrix is denoted by the row and column difference vector (r - c). As the row and column difference vector of "organization" was observed to be above zero (1.07), it can be deduced that the influence of "organization" on other dimensions is superior to that of other dimensions on "organization". This situation identifies "organization" as the transmitter. In addition, the "organization" and "technology" factors of the system in this model can be considered causal, while the "human" factor can be considered effective. The process described above is applicable for the variables in all dimensions.

Table 4. Total effects and net effects for each variable

Human Variables				
V1 Individual Competences and Skills	1.77	0.91	2.68	0.86
V2 Trust	1.66	0.88	2.54	0.78
V3 Motivation	1.45	0.61	2.06	0.84
V4 Privacy	1.31	0.16	1.47	1.15
V5 Intellectual Property	0.66	0.23	0.89	0.43
Technological Variables				
V6 Collaboration System	1.54	0.55	2.09	0.99
V7 CRM Technology Infrastructure	1.32	0.42	1.74	0.90
V8 Knowledge Map	1.27	0.23	1.50	1.04
V9 Integrated Knowledge Repository	1.19	0.19	1.38	1.00
V10 Social Media	1.13	0.21	1.34	0.92
Organizational Variables				
V11 CKM Strategy Development	1.91	0.66	2.57	1.25
V12 Customer Involvement	1.94	0.73	2.67	1.21
V13 Customer-Centric Culture	1.79	0.72	2.51	1.07
V14 Cross-Functional Cooperation	1.68	0.45	2.13	1.23
V15 Top Manager Support	1.66	0.33	1.99	1.33
V16 Training	1.54	0.29	1.83	1.25

V17 Key Customer Support	1.46	0.27	1.73	1.19
V18 Reward System	1.55	0.24	1.79	1.31
V19 CK Oriented BP	1.34	0.21	1.55	1.13
V20 CK Quality	1.24	0.18	1.42	1.06
V21 Program Champion	1.19	0.17	1.36	1.02
V22 Community of Practice	1.16	0.11	1.27	1.05

Table 4 presents the results attained for the variables through the application of DEMATEL. The level of significance with regard to the various influence factors is realized through the addition of an influential factor's given (ri) and received (ci) total effects. As shown in Table 4, the application of the total relation matrix determines and denotes the status of the factors thereby revealing their overall significance. Table 4 also discloses that the DEMATEL investigation served to identify the factors that mainly influenced others, as well as those that are prone to influence by others. It can be observed that with the superior value of r + c (2.68) for "Individual Competences and Skills", the "human" factor establishes itself as most influential. In the "technological" dimension, "collaboration system" is perceived to have a considerable influence (r + c = 2.68) on other factors, and in the "organizational" dimension, it is the influence of "Customer Involvement" (r + c = 2.67) that is deemed highest.

7. ANP ANALYSIS

Following the application of DEMATEL to determine the degree of interdependency between the dimensions and variables, the ultimate influences and priority of three dimensions and their variables were ascertained through the ANP process. In accordance with the ANP model and relationship configuration between dimensions and variables, a questionnaire with pairwise queries was distributed to 30 specialists. These specialists come with sufficient knowledge on the use of CKM in the realm of software development. With a response rate of 100%, all the questionnaires were deemed applicable. The participants of this survey were directed to register their responses to the pairwise queries according to a scale ranging between 1 and 9. An example of the questions posed to the participants was, "in the context of CKM in software development enterprises, how much more significant is the "human" factor in comparison to the "organization" factor?" In the nine-point Saaty scale for rating the significance level of one component over another (dimension as well as variable), a score of 9 signifies great significance, while a score of 1 signifies equal significance. Subsequent to the calculation of the results attained through the survey, all the Consistency Ratio (CR) values were found to be satisfactory, while the eigenvectors exhibited were deemed suitable for entry into the super matrix. As for pairwise comparisons, the first stage of this process entails the creation of a pairwise contrast matrix for the "technology", "organization" and "human" dimensions. Distinct comparison matrices will take shape based on the relationships between dimensions. The attained comparison results involving the dimensions are portrayed in Table 5.

Table 5. Comparison of the 3 dimensions with respect to the overall goal

With Respect to the Goal	Organization	Technology	Human	Weights
Organization	1.0	8	5	0.757
Technology		1.0	2	0.139
Human			1.0	0.102
CR = 0.07 (desirable value to be less than 0.100)				

During the second stage, based on the relationships existing between them, pairwise comparisons are conducted for every variable in the dimensions. The experts are required to replied to a sequence of pairwise contrasts in which a pair of variables is compared simultaneously in accordance to an upper level control criterion. The pairwise comparison executed for elements at each level is based on their influence in relation to their control criterion. From the viewpoints forwarded by the specialists, it was gathered that "Individual Competences and Skills" (influence weight of 0.37), "Collaboration System" (influence weight of 0.44) and "Customer Involvement" (influence weight of 0.20) represent the most significant variables in the "human", "technology" and "organization" dimensions respectively. This is an indication that the most significant factors in the "human" dimension are "Individual Competences and Skills" and "Trust". The specialists are in concurrence that in the "technology" dimension, "Collaboration System", "CRM Technology Infrastructure" and "Knowledge Map" are more significant than the other factors. They are also of the view that "Customer Involvement", "CKM Strategy Development", "Customer-Centric Culture", "Cross-Functional Cooperation" and "Top Management Support" are significant in the organization dimension. According to the ANP survey, the specialists engaged in software development are in agreement that the factors mentioned during this study ought to be considered prior to the application of CKM. The considerably greater weights exhibited by the Technology and Organization dimensions reflect their significance in the eyes of the specialists.

8. CONCLUSIONS

During the realization of this research, almost 69 % of enterprise software development companies didn't have any solution or guidelines for gathering and application of customer knowledge, thus, this study tries to investigate the crucial CKM factors in a software development context.

This research is based on the "Generic CKM Model" which included Knowledge-Based View theory and the theory of Technology. According to the Generic CKM Model, we investigated "human", "organizational" and "technological" CKM antecedent factors. 22 factors under three dimensions which are crucial for the implementation and deployment of CKM in different contexts were selected using the literature review. However, in order to achieve the objectives of this research, the significance of these factors for enhancing CKM and improving software quality in the field of enterprise software development needs to be confirmed. Hence, a hybrid MCDM model consisting of ANP and DEMATEL was applied to evaluate the proposed conceptual model by conducting a survey questionnaire among 30 experts.

DEMATEL method was used to identify the interdependencies between dimensions and their pertinent variables and ANP has provided the weight and priority of the variables in each dimension. The outcomes show that from the specialists' viewpoint, "Customer Involvement" and "CKM Strategy

Development" were the most significant factors in the "organization" dimension. In the second dimension (technology), the specialists approved that the "Collaboration System" and "CRM Technology Infrastructure" were more crucial compared to the other factors. Furthermore, in the "human" dimension, "Individual Competencies and Skills" and "trust" were considered more eminent than others.

The outcome of this research specified that the experts in the software development context suggested that these antecedent factors should not be ignored by the managers of software companies in order to have a successful CKM plan. The results indicate that the weight of the "organization" and "technology" dimensions are considerably higher than the "human" dimension, while "organizational" and "technological" conditions can enable and facilitate the "human" dimension. For instance, training and using a collaboration system can enhance the skills of employees for absorbing, sharing and applying customer knowledge to improve software quality.

Finally, the empirical analysis of the study did not make a distinction between tacit and explicit knowledge. Thus, future studies should examine in more detail the effect of the nature of knowledge on the CKM and its relationship with software quality.

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CONTACTS

Assoc. Prof. RNDr. Tibor Krenicky, PhD.

Technical University of Kosice
Faculty of Manufacturing Technologies
Department of Technical Systems Design and Monitoring
Bayerova 1, 080 01 Presov, Slovakia
Tel.: +421 55 602 6337
e-mail: tibor.krenicky@tuke.sk