Supporting Targeted Selection of Collaboration Tools for Distributed Software Development

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***Abstract*—Many distributed software development teams lack targeted selection of collaboration tools, as project- and team-specific requirements are not taken into account for work support. For effective and efficient distributed team work, case-sensitive requirements engineering could help through adapting support tools to project situations. In this contribution, we detail method requirements for selecting collaboration tools for a given development context. We also analyze existing decision support techniques with respect to context adaptation. The Hybrid Knowledge-Based System (HKBS) method not only supports the context-sensitive identification of criteria, but also the selection of collaboration tools based on the development requirements. A corresponding web-based tool has been developed and evaluated in an empirical field study. The gained insights reveal the potential of HKBS and the respective tool support for targeted selection of collaboration tools in software development.**

Keywords–Global Software Development; collaboration tools; project-specific decision support; Hybrid Knowledge-Based System

I. INTRODUCTION

Globalization has affected software development and changed the manner in which software engineering projects are carried out. Software development is more and more seen as a globally distributed and multi-cultural endeavor [1][2]. This trend towards globally distributed software projects is facilitated by the widespread availability of high-speed Internet access. The distribution of projects and teams over several sites allows access to qualified workforce around the globe and enables the leverage of time zones to shorten software development cycles and time to market [3][4]. As software engineers are geographically distributed over different time zones, the time difference allows for 24-hour development (also known as "round-the-clock" or "follow-the-sun" development) facilitating a shorter project duration [4][5]. Despite the benefits of Global Software Development (GSD) new challenges arise with multi-site projects affecting communication and coordination. Due to the distance between sites, not only a drop in the frequency of communication but also reduced communication efficiency can be observed [6][7]. Communication, however, is essential for collaboration and teamwork and ultimately for the success of a project [4]. Consequences of inefficient communication can manifest in increased costs, delay, or even the discontinuation of a project [3][7][8].

In GSD, collaboration tools are used to address these challenges and support cross-site team communication. But often the collaboration tools in use do not provide adequate support for the team to ensure efficient communication [9][10]. This can be traced back to the fact that the selection of communication tools is often not aligned with the team's and the project's requirements [10]. As argued by Christian and Rotenstreich [10], an evaluation method is missing to better align the selection of collaboration tools.

In Section II, the requirements for project-specific selection of collaboration tools are inferred based on existing literature. Furthermore, existing decision support methods are analyzed based on these requirements. Criteria are required for the application of decision support methods. Relevant selection criteria for collaboration tools are presented in Section III. The results of an empirical field study are presented in Section IV. In Section V, the findings of the field study and their implications are discussed and put into context with existing literature results.

II. DEMAND FOR FLEXIBLE DECISION SUPPORT

Requirements for decision making are inferred based on the given decision context and are represented as criteria in the decision making process [11][12]. In the case of collaboration tool selection, the decision context is mainly defined by organizational and project specific factors. Picking up the proposal of Christian and Rotenstreich [10] to further investigate evaluation and selection support for collaboration tools, it becomes apparent that every project situation is unique [13]. Due to this uniqueness of the project situation and, therefore, the decision context a completely predefined set of criteria for the selection of collaboration tools is not viable. Criteria have to be selected in accordance with the decision context to reflect the needs of the organization, project, and team [13][14]. Hence, a decision method to support the selection of collaboration tools should support the context-sensitive identification and selection of criteria and should further provide enough *flexibility* to be applied in different project contexts with changing requirements and criteria.

The identification of such a decision support method to facilitate targeted selection requires a more fine-grained definition "flexibility" in this particular domain. The understanding of flexibility presented herein comprises of two aspects: 1. representation of the decision context 2. adaption of existing models to changes of the decision context in order to facilitate decision model reuse. A fundamental requirement for the representation of the decision context in the decision making process is that the decision support method is able to include all relevant criteria of the given decision context. The selection of collaboration tools and, more generally speaking, software

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products, can be categorized as a Multi Criteria Decision Analysis (MCDA) problem [13][15][16][17]. In MCDA, decision support methods need to be able to handle multiple criteria, which influence the decision making [18][19]. Furthermore, the combination of qualitative and quantitative criteria having no common unit of measurement is often relevant for the selection process.

Although a fixed, predefined set of criteria for the selection of collaboration tools is not advisable, reuse of existing decision models can be beneficial to shorten the decision making process. For instance, within an organization constant criteria which are used for every software selection will exist. By providing decision models incorporating these criteria as a starting point would only require to include the project-specific aspects and, therefore, decreasing the overall selection effort.

This leads to the following criteria for flexible decision support methods:

- Support of qualitative and quantitative criteria
- Handling of incommensurable units of measurement
- Handle dynamically changing criteria and alternatives
- Support identification and negotiation of criteria
- Adaptability of existing models (facilitate reuse)

According to a literature review conducted by Jadhav and Sonar [20], the Analytic Hierarchy Process (AHP) and the Weighted Sum Method (WSM) are the most prominent decision support methods in the context of Commercial-Of-The-Shelf (COTS) software selection. Knowledge-based decision support methods are also suited and established in the area of software selection [21][22]. In [22], a new approach to decision support, called Hybrid Knowledge-Based System (HKBS), using a hybrid knowledge-based approach is introduced. This new approach addresses relevant aspects for software selection, namely *flexibility* and *reuse*, and therefore is included in this analysis.

Analytic Hierarchy Process

AHP, introduced by Thomas L. Saaty [11][23], is a scientifically well-examined and widely-used decision support method [24]. AHP is based on the principles of *decomposition* and *relative judgments* [23]. The representation of the decision problem is based on the decomposition of the selection goals in subgoals and, ultimately, criteria resulting in a hierarchical structure. Criteria weights (i.e., the importance of each criterion) are assigned by relative comparisons on each level of the hierarchy. For this purpose a predefined scale is used. The effort needed for these pair-wise comparison depends on the number of criteria. The number of needed pair-wise comparisons can be calculated as shown in Equation 1 [22, p. 1401].

$$Comparisons = M * \frac{M-1}{2} * N \quad (1)$$

For example, in an evaluation involving four alternatives and nine criteria this would result in 54 pair-wise comparisons. Adapting the criteria hierarchy or adding an additional alternative requires to redo at least some of the comparisons. This limits the flexibility in terms of adaptability and reuse of existing models and alternatives [20]. Reusing existing decision models, respectively hierarchies, is possible to some extent, but the relative values used for comparing criteria and alternatives require to repeat at least some of the pair-wise comparisons [20].

Weighted Sum Method

WSM is considered an easy to use decision support method [15]. Each criterion used in selection process a numerical weight is assigned to express the importance of the criterion. The assigned weights are multiplied with the corresponding criterion value. The resulting values are than added up to the final score. According to WSM, the alternative with the highest score is the most suited alternative. This approach implies that only quantitative variables with the same unit of measurement can be used [15][22]. In MCDA, problems usually criteria with incommensurable units are involved and, therefore, WSM is more suited for single dimension problems [15][25]. Although the use of qualitative criteria is in principle not supported, qualitative criteria can be included in the decision process when the values are transformed to numeric values beforehand. But again, this is only valid when all other criteria are measured using the same scale [15].

The selection and assignment of criteria and weights is not supported by a defined process. This could lead to difficulties in assigning the criteria values, especially when dealing with a higher number of criteria [22].

Hybrid Knowledge-Based System

A new approach to knowledge-based decision support, which explicitly addresses flexibility, adaptability, and reuse, is introduced in [22]. HKBS combines deductive and inductive reasoning in one decision support method by including Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR) in the approach. The HKBS method, which is illustrated in Figure 1, not only covers the evaluation process itself but also covers the selection of criteria.

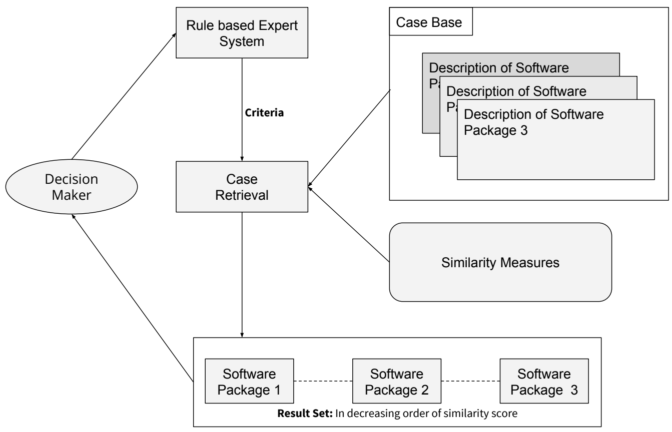

Figure 1. Components of the HKBS method according to [22, p. 1399]

HKBS allows the use of quantitative as well as qualitative criteria. Based on a rule-based system and the included expert knowledge, the requirements of the stakeholders are elicited and a suggested criteria set is derived. This suggestion can be altered and adapted by the decision makers in terms of the selected criteria as well as the assigned scales. The final set of criteria and scales is then used in the CBR process. The decision makers need to define and enter criteria values for each alternative. Alternatives combined with the assigned criteria values, so called *cases*, are stored in the *case base* of the CBR system. Cases stored in the case base can be edited (e.g., add new criterion) and can be reused in different query. For example, if the collaboration tool X was already entered in the case base for a selection in project *p*, it can be directly used for selection in project *r* independently of the criteria set used.

Analysis

Comparing the decision support methods based on the previously inferred criteria shows that HKBS has the potential in terms of providing flexible decision support. In connection with the case base, the CBR component allows the reuse of data entered in the system in upcoming decision processes.

Due to its applicability in several areas of application AHP is known as a flexible decision support method [26]. Nonetheless, the flexibility concerning the reuse of existing decision models is limited due to the principle of comparative judgments [22]. Due to these pair-wise judgments adapting the criteria hierarchy or adding an additional alternative requires to redo at least some of the comparisons. The adaptability of a WSM decision model depends on whether the criteria weights are in relation (e.g., sum of all weights has to be 100%) or not. If the criteria are in relation the criteria weights have to reassigned if the decision model is changed; otherwise a reassignment is not needed.

Both HKBS and AHP support qualitative and quantitative criteria, whereas, WSM does not support qualitative criteria. Qualitative values have to be transferred to numerical values to be used in the WSM decision model potentially leading to invalid decision models [15].

The comparison of the methods shows that HKBS has the potential in terms of providing flexible decision support according to the defined requirements. The HKBS method relies on the in encoded expert knowledge, which consists of criteria catalog and rules to infer the criteria suggestions, and on adequate tool support [22]. Due to the CBR and RBR components of the method, HKBS is based on complex calculations. Therefore, tool support is needed to enable a practicable application of the method [20]. In order to meet this requirement, a criteria catalog for the selection of collaboration tools has to be identified and a tool supporting the HKBS method has to be provided.

III. Identifying Relevant Criteria for Collaboration Tool Selection

The selection of collaboration tools comprises general aspects of software selection and, on a more specific level, aspects of collaboration. General criteria software selection criteria for the use with the HKBS method have already been elaborated by [22]. In a literature review, Jadhav and Sonar identified six core categories, which are applicable for software selection in general [22]. These categories are illustrated in Figure 2. Furthermore, the authors inferred the need for a seventh category dealing with functional criteria. These criteria are specific to type of the evaluated software and its area of application. Therefore, these criteria need to be specified for each application area individually [22]. In the case of collaboration tools, this would be those features and functionalities addressing specifically collaboration support (e.g., collaborative meeting scheduling).

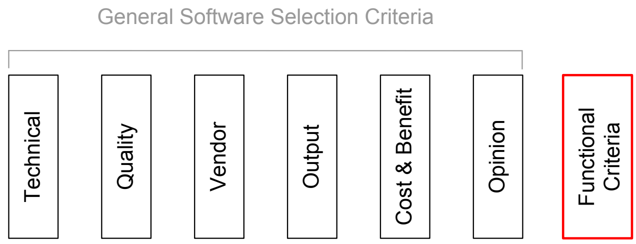

Figure 2. Software Selection Categories [22]

Distance is a limiting factor to team communication and collaboration [27][28]. In GSD projects, collaboration tools are used to overcome communication and collaboration problems caused by distance and distribution [27][29]. In order to be able to identify criteria relevant for collaboration tool selection, an understanding of how distance affects collaboration is needed. “Distance” in GSD is not only limited to the geographical separation. The term “distance” involves besides the geographical distribution of development teams also their socio-cultural diversity as well as the time difference across various sites [6][27][30].

These dimensions of distance have negative effects on three essential aspects of collaboration [27][31]: *Communication, coordination and control*. Additionally to these three aspects discussed by [31], *trust* within an team – an additional factor for successful collaboration [32] – is affected. An approach to overcome these challenges and limitations is to *provide appropriate communication channels and media* which are capable of supporting the different aspects of collaboration and communication across sites [33]. Based on existing findings, following functions could be identified for facilitating communication, control and trust building and, therefore, provide collaboration support.

- Forum/Discussion Board [27][34]
- Instant Messaging [35][36]
- Wikis [37][38]
- Blogs [27][34]
- Collaborative Calendars [10][39]
- Meeting Request/Scheduling [10]
- Task/Bug Tracking [40]
- Time/Project Planning Support [40]
- Shared Workspaces [10][41]
- Work Social Networks [42][43]
- Video Conferencing/Telephony [44]

IV. Empirical Field Study

An empirical field study was performed at *msg systems* in Passau, Germany. Results were collected using expert interviews. The expert interviews were conducted in a group setting based on the method described in [45, p. 363ff]. The designed interview guideline focused on flexibility and adaptability of the decision support method, the preselection of collaboration specific criteria and the criteria selection support. In order to check whether the preselection of criteria does not interfere with the flexibility and adaptability of the method a question targeting the flexibility of the criteria selection was included. The guideline was checked in terms of comprehensibility and structure in individual pretests involving two participants.

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A. CollabSelect - Prototypical HKBS Implementation

At the time of this study neither an open source nor a commercial implementation of a HKBS tool was available. Subsequently a brief description of design and implementation of a prototypical HKBS tool called "CollabSelect" is given. The goal of the implementation was to provide tool support for the HKBS method, including the guided selection of criteria, especially in terms of the flexibility of criteria and scales.

CollabSelect has been implemented as an web-based tool using Java Server Faces (JSF). For the realization of the CBR components, an existing Framework called "myCBR" was used [46]. Criteria are provided using an xml file which can be changed at runtime. Scales can be defined either in the xml file directly with the criteria or using the GUI editor implemented in CollabSelect. CollabSelect provides support for the entire HKBS method including:

- Support of criteria selection (on the basis of [22])
- Adaptability of criteria and scales
- Case management & reuse of existing cases
- Query execution & presentation of results
- Export to myCBR workbench

B. Field Study Setting

Using the developed tool, the HKBS method has been tested in two GSD projects. The goal was to provide indicators whether the HKBS method is able to support flexible and targeted selection of collaboration tools. The field study involved four participants assigned to two distributed projects filling different positions in the organization. All participants were involved in other distributed software developments projects prior to the current projects. Both involved projects are distributed over Europe, including sites in Passau/Germany, Cluj/Romania, and Hagenberg/Austria. 22 respectively 6 to 15 employees, depending on the workload, are assigned to the projects.

C. Method & Approach

The selection of the participants complies with the expert definition presented in [47]. Based on this definition, a project manager, an assistant project manager, and two developers were selected as participants. Results were collected using the expert interview method conducted in a group setting as described in [45]. The selected interview method requires an interview guideline to structure the interview. The designed guideline focused on flexibility and adaptability of the decision support method, the preselection of collaboration specific criteria, and the criteria selection support. In order to check whether the preselection of criteria does not interfere with the flexibility and adaptability of the method, a question targeting the flexibility of the criteria selection was included.

Prior to the field study the participants individually reflected based on their experience upon relevant aspects and criteria in terms of the selection of collaboration tools. The main part of the field study was an exemplary selection process of a collaboration tool for the participants' current projects. This selection was based on the procedure given by HKBS:

1) Criteria Selection
2) Case Creation
3) Querying the System
4) Adaption of Criteria & Scales
5) Re-Querying the system using adapted scales

This selection process was also conducted in a group involving all the participants. This setting enabled the inclusion of all decision makers in the discussion about criteria and criteria weights. Directly after the selection process the group interview was conducted based on the designed interview guideline.

D. Results

Following, the results of the audio recorded interview are aggregated and presented according to the interview guideline.

Preselected General and Functional Criteria: The preselected software selection criteria were seen as rather coarse grained covering a wide range of aspects. This leads to the usage of just small subset of the preselected criteria. However, this was not experienced as cumbersome, but rather as an advantage when selecting other types of software. Criteria which were not relevant in this context may be of relevance in a different selection context. The participants noted that the relevance of criteria does not only depend on the project situation but is also influenced by the involved decision makers and their roles.

The identified collaboration related, functional criteria have been perceived as adequate and in accordance with the participants' expectations. The participants mentioned that it would be useful to use more fine-grained functional criteria. The idea was to use the identified functional criteria as a starting point and detail the criteria based on use cases in the project. However, the participants stated that this would have to be done in every project situation separately, since the relevant use cases vary from project to project. Therefore, this would be in the responsibility of the decision makers and should be provided as an additional step in the selection process.

Flexibility of Criteria Selection: The participants perceived the selection of the criteria as "highly adaptable". Especially the possibility to adapt the suggested criteria set in terms of removing or adding criteria contributed to the flexibility to the criteria selection process. According to the participants, additionally the customizability of scales contributed to the overall flexibility.

Support of Criteria Selection: The step of criteria selection triggered intensive discussions about the requirements in the project. The participants stated that this discussion supported the identification and understanding of the relevant project-specific criteria. The criteria suggestions provided by the tool and the resulting discussions helped to identify relevant criteria which have not been seen as relevant beforehand. One of the participants noted that the tool supported suggestion of criteria may cause the decision makers to be too focused on the suggested criteria hindering them to consider additional aspects. His suggestion was that each decision maker individually reflects upon relevant criteria before the actual selection process, as done before the study, to minimize the bias caused by the criteria suggestion.

Inclusion of Relevant Criteria: The participants were asked whether all, in their opinion relevant criteria could be represented by the decision support method. Due to the support of qualitative as well as quantitative criteria and the adaptability of the criteria set, all relevant criteria could be represented in the decision model. Relevant criteria which were not included in the criteria set could be added ad hoc during the criteria selection.

Adaptability of Tool Selection Regarding the Project Situation: The participants considered the selection using the HKBS method as adaptable. Different selection contexts can be represented using this method. The flexibility of the criteria set and scales are seen as an important aspect supporting this adaptability. However, the participants interposed that the selection of collaboration tools in a project situation might not be suitable to evaluate this aspect, since, according to their past experiences, decisions about collaboration tools are made company-wide not on project level.

Suggestions and Improvements: The adaptability of criteria and scales lead to the demand for the possibility to annotate changes. According to the participants documenting rational for changes would be beneficial for understanding what lead to certain decisions. Furthermore, also annotating the selected criteria values when creating the alternatives was requested. Especially when dealing with qualitative criteria this would again facilitate the traceability of the given criteria values.

The participants requested, in order to facilitate the adaption of criteria and scales, that additionally to the suggestion of criteria, also a set of predefined scales should be included. The adaptability and customizability is already given but would additionally be supported by this enhancement. Moreover, a participant suggested that methodological support for defining scales, especially for qualitative scales, would facilitate the customization of scales.

V. Discussion

The study revealed advantages and shortcomings of the application of the HKBS method for collaboration tool selection. The inclusion of all relevant criteria (types) and the criteria selection support were seen as positive features of the HKBS method. Comparing HKBS and AHP in terms of the inclusion of several criteria types no real advantage of either method can be found in literature [11][22]. So it is arguable that these advantage for selecting collaboration tools applies also for other methods supporting various criteria types.

Looking at the criteria selection process the study shows that further support is needed. Considering these results the explicit inclusion of guided criteria selection in HKBS seems beneficial. Future studies should focus on how criteria selection support can be further improved. Compared to HKBS, AHP is in literature and practice the more prominent decision support method [26]. Combining the context-specific criteria selection support of HKBS with the profound decision support approach of AHP could provide a comprehensive selection support. Having developed this extension of AHP an extended survey comparing HKBS and AHP in different application areas would be of interest.

Concerning the reuseability and adaptability of decision models the results lessen the alleged advantage as discussed by [22], at least for the selection of collaboration tools. In other areas of application, reusability might be more beneficial.

VI. Conclusion

Collaboration tools provide support for distributed development teams. In order to provide adequate support, collaboration tools need to be selected based on the requirements in the project. Indicators were found that the HKBS method enables targeted selection of collaboration tools taking the specifics of the project situation into account. Also, shortcomings of the HKBS method have been identified. In addition, the results of the field study show that decision makers lack methodological guidance in customizing criteria and scales to reflect the given project situation. It was suggested to enhance the selection process with an additional upstream step. In this step, the fine-grained requirements and criteria should be identified based on project-specific use cases. This insight may also be beneficial for extensions of other decision support methods.

This initial study provides a basis for future studies, to verify the herein presented results and suggestions in multiple project settings including more participants.

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