AN EMPIRICAL STUDY TO COMPARE THREE METHODS FOR SELECTING COTS SOFTWARE COMPONENTS

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Component Based Software Developers are faced with the challenge of selecting appropriate Commercial Off-The-Shelf (COTS) products, because the marketplace is characterized by a variety of products and product claims, extreme quality and capability differences between products, and many products incompatibilities. Although a multiplicity of COTS selection method have been proposed in literature, most developer still select COTS products using ad hoc methods. One of the main reason being, COTS selection method do not provide all or most of the required support and guidance required for carrying out the COTS selection process. Moreover, literature on COTS selection methods rarely mentions the limitations of the methods. Therefore, we carried out an empirical study to compare three COTS selection methods; the process and results of the study are presented in this paper. The main objective of the study was to point out the differences between the COTS selection methods, that is if any existed, and to determine the ability of each of the methods to provide adequate COTS selection support and guidance. The ability of a method to provide adequate COTS selection support and guidance was measured in terms of the user satisfaction and confidence in the selection process, as well as in the results of the process.

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1. INTRODUCTION

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The use of Commercial-Off-The-Shelf (COTS) is increasingly becoming common because of shrinking budgets, accelerating rates of COTS products enhancement, development time and effort constraints, and expanding system requirements. Generally, COTS software products have the ability to reduce time and cost of software development (Wanyama et al., 2005)2. Moreover, they enable software buyers to acquire software made up of components, which have been tested many times by other users; hence ensuring improved software quality (Alves et al., 2003)2. However, in order to realize the benefits which COTS products bring to software development, it is imperative that the "right" products are selected for projects, because selecting inappropriate products may result in increased time, cost, and effort requirements for software development; which COTS-Based Software Development (CBSD) aims at reducing. The selection of COTS products is a major challenge to COTS-Based Software developers, due to the multiplicity of similar COTS products on the market with varying capabilities and quality differences. Moreover, COTS selection is a complex decision-making problem that is characterized by uncertainty, complexity, multiple stakeholders, multiple objectives (Wanyama et al., 2005)2. To address these challenges, it is generally agreed in literature that robust COTS selection methods are necessary (Alves et al., 2003)1 , (Bianchi et al., 2002), (Cavanaugh et al., 2002), (Kontio et al., 2000), (Ruhe, 2003). Consequently, many COTS selection methods have been proposed. Unfortunately, none of these methods is accepted as a standard selection method. Moreover, the selection of COTS products is largely still carried out using ad hoc methods (Ruhe, 2003), (Wanyama et al., 2005)2. The most unfortunate thing about all this is that researchers in COTS selection are continuously proposing new COTS selection methods without taking a break to evaluate available methods based of the users needs through empirical studies. This would assist in identifying the major COTS selection challenges that users of COTS selection methods need to be addressed.

Curious about why the industry had failed to adopt some of the proposed COTS selection methods in literature to address the challenges of COTS selection, we studied the COTS selection problem and identified the following major challenges associated with the problem:

- Generation of high-level information used for decision-making
- Need for hierarchical decision-making
- Many similar COTS products
- Multiple COTS selection objectives
- Changing COTS features due to updates
- Multiple Stakeholders
- Management of information for the current and previous COTS selection processes
- Selection of COTS products for the different subsystems

Thereafter, we evaluated the following eleven most prominent COTS selection methods based on how they address the challenges that we identified: Off-The Shelf Option (Kontio et al., 2000), Comparative Evaluation Process (Cavanaugh et al., 2002), COTS-based Requirements Engineering (Alves et al., 2003)[1] and (Alves, 2003), COTS-Aware Requirements Engineering (Chung et al., 2002), Procurement- Oriented Requirements Engineering (Ncube et al., 2003, COTS Acquisition Process (Ochs et al., 2000), QUESTA (Hansen, 2003), Storyboard (Comella-Dorda et al., 2002), and, Socio-Technical Approach to COTS Evaluation (Kunda et al., 1999), PECA (Comella-Dorda et al., 2002), and Combined Selection of COTS Components (Burgues et al., 2002). Furthermore, we reviewed the COTS selection methods to determine the extent each of them had been employed in industry. In this study we found out that none of the COTS selection methods that we evaluated addressed at least, 50% of the selection challenges. Moreover, we found out that most of the methods had never been applied in industry, and that the few that had been applied before, had been employed by the people who developed them or who sponsored their development (see Wanyama and Far (Wanyama et al., 2005)[2]).

Having identified the challenges of COTS selection and the shortfalls of the reviewed COTS selection methods, we developed a framework for COTS selection at the University of Calgary, which comprises of a process model as well as an associated Decision Support System (DSS) (See Wanyama and Far (Wanyama et al., 2005)[1]). This framework addresses the first seven challenges mentioned above. Thereafter we carried out an empirical study involving the framework we developed and three other prominent COTS selection methods to determine the views the users of COTS selection methods on the functionalities of the methods. Our concern at this moment was to determine the major concerns of the users of COTS selection method that would assist us to improve our framework for COTS selection. The focus of this paper is not the framework for COTS selection that we developed, but the empirical study that we carried out as part of the validation of the framework. Therefore, the main objective of this paper is to draw attention to the functionalities of COTS selection methods that people involved in the selection of COTS products find to be important. We believe that results of this study are needed to assist developers of COTS selection methods to identify the issues that need to be addressed.

This paper is arranged as follows; Section 2 presents work that is related to the focus of this paper, and in Section 3 we describe the COTS selection methods that were evaluated in the empirical study. Section 4 deals with the design of the empirical study, while Section 5 addresses the process of the study. In Section 6 we present the results and in Section 7 the results presented in Section 6 are discussed. Section 8 deals with the threats and limitations of the empirical study, and Section 9 presents the conclusions and future work.

2. RELATED WORK

Empirical studies have been used in many cases to identify, to learn about, and to address various issues that affect CBSD. For example, Bianchi, Caivano, Conradi and Jaccheri (Bianchi et al., 2002) carried an empirical study to assess the COTS products' characterization parameters that they proposed. The main objective of the assessment was to find any statistically significant relationship between the proposed parameters and the effectiveness of development and maintenance process. Li, Bjornson, and Conradi (Li et al., 2004) carried out an empirical study to determine the variations in the CBSD processes in the Norwegian Information Technology (IT) industry. The study identified four activities that were specifically associated with CBSD, namely: build vs. buy decision, selection of COTS products, learning and understanding COTS products, integration of COTS products. Furthermore, the study identified a new software development role, that of the knowledge keeper. Li, Conradi, Bunse, and Torchiano (Li et al., 2006) report an international survey that was carried out in Norway, Italy and Germany. The focus of the study was to determine why project decision-makers choose to use Open Sources Software (OSS) instead of COTS products and vice versa. The survey covered 83 projects that used COTS products only and 44 projects that used OSS only.

This paper presents an empirical study that was carried out in the department of Electrical and Computer engineering at the University of Calgary, to validate a framework for COTS selection, which we developed. The validation process was carried out by comparing the framework with two COTS selection methods in literature, in terms of the ability to facilitate the process of COTS selection. The two methods: the Comparative Evaluation Process (CEP) and the COTS-based Requirements Engineering (CRE) were selected for the experiment because they are some of the few COTS selection methods that have been applied in practice.

3. DESCRIPTION OF THE COTS SELECTION METHODS THAT WERE STUDIED

The following is a brief description of CEP, CRE, and the framework for COTS selection that was developed at the University of Calgary.

3.1 The Comparative Evaluation Process Selection

The Comparative Evaluation Process (CEP) is presented in detail in Cavanaugh and Polen (Cavanaugh et al., 2002). The COTS evaluation method is based on a spreadsheet model which assists decision maker when comparing similar COTS products based on the discrimination criteria. The decision model is based on the decision theory model of simple weighted averages. The simple averages model is applied to each evaluation criterion as follows:

- Define the importance weight (local weight) of the criteria categories
- Define the importance weight (local weight) of every criterion in each criteria category.
- For each criterion, determine the product of the criteria weight and the weight of the corresponding criteria category to determine the global weight w_i of the criterion i .
- Define the performance weight P_i of every alternative COTS product in each evaluation criterion i .
- Select the credibility score c_i of every criterion i for each product p from Table 1. The credibility score of a criterion is determined by the sources of information for the COTS product, about the features of the product associated with the evaluation criterion [9].
- Determine the performance score ($Pscore_p^K$) of each product p in every criteria category K using Equation 1.

$$Pscore_p^K = \sum_{i=1}^{n} \frac{P_i w_i c_i}{100} \quad , \qquad (1)$$

where n is the number of criteria in category K, and the one hundred in Equation 11.1 is a normalizing factor for maximum score of a hundred.

- The final score ($Fscore_p$) of each product p , that reflects the ability of the product to satisfy the project conditions is determined using Equation 2.

$$Fscore_p = \sum_{K=1}^{M} Pscore_p^K \ , \qquad (2)$$

- M is the number of criteria categories.

Credibility	Value	Description
Verified	10	Verified by the decision maker
Demonstrated	7	Witness in a demonstration
Observed	5	Seen but have not been studied
Heard/Read about	3	Described by another user or vendor, or read about in vendor documentation

Table1: Rating of the Credibility of Information Sources

Table 2 illustrates the process of defining the criteria global weights. The table shows that the quality criteria category has a local weight of 75% and the business concerns category has weight of 25%. In addition, the table shows that the local importance of reliability is 30%, thus the global weight of reliability is 22.5%.

First Level of Criteria Hierarchy (local weight)	Second Level of Criteria Hierarchy (local weight)	Global Weight
1. Quality (75%)	1. Reliability (30%)	22.5%
	2. Security (70%)	52.5%
2. Business Concerns (25%)	1. Products Price (50%)	12.5%
	2. License Conditions (50%)	12.5%
Total		100%

Table 2: Example of Global Weight Calculation

Since CEP does not have a specific model for information sharing, the subjects using it were allowed to use any of the following communication means for information sharing: face-to-face meetings, telephone, email and/or web page.

3.2 COTS-based Requirements Engineering

COTS-based Requirements Engineering (CRE) is presented in Alves, and Castro (Alves et al., 2003)[1] and in Alves (Alves, 2003), The method requires that selection of COTS products be based on the balance between estimated cost and estimated benefit that the products may bring to the project. However, the method does not provide any guidance on how to achieve the balance between the estimated cost and benefit. Therefore, the subjects who used CRE were allowed to make their final COTS selection decision based on their view of balance between cost and benefit associated with the COTS products.

The MCDM model in Equation 3 is used to estimate the ability of the alternative COTS products to satisfy the quality requirements of the project.

$$Score_j = \sum_{i=1}^{k} a_{ji} w_i \ , \qquad (3)$$

where $Score_j$ is the ability of COTS product j to satisfy the project conditions, k is the number of evaluation criteria, a_{ji} is the strength of COTS product j in criterion i , and w_i is the weight of criterion i . Moreover, the total estimated cost of each product was determined by adding up all the costs associated with the product. Since the method does not have a specific model for information sharing, the communication methods stated in Section 3.2 were used.

3.3 Framework for COTS Selection

The framework for COTS selection is presented in Wanyama and Far (Wanyama et al., 2005)[1]. It has a process model that guides the users through the various steps of COTS selection, as well as an integrated web-based Decision Support System (DSS) that has the following functionalities:

- Support for defining the evaluation criteria and the criteria weights.
- MCDM model for integrating the performance of the alternative COTS products in each evaluation criteria into scores that reflect the ability of the products to satisfy the project conditions.
- Negotiation support for multiple stakeholders and for multiple selection objectives
    1. Support for identification of agreement options, and for determining a balance among selection objectives
    2. Support for tradeoff.
- Inbuilt discussions web-page
- Inbuilt email communication with auto notification capabilities
- Support for access to expert information.
- Support for access to lessons-learned from previous COTS selection processes

4. DESIGN OF THE EMPIRICAL STUDY

Fifteen software engineering students in the Department of Electrical and Computer Engineering at the University of Calgary were the subjects of this study. Eleven of the students were in the final year of the undergraduate degree course, and four students were postgraduates. The target population of subjects was the senior students of Software Engineering, because such students have some background knowledge of COTS-based or at least component-based software development.

Seventeen students applied to participate in the study as subjects of the study, and since we wanted to have three groups with equal number of subjects, we selected fifteen subjects by assigning numbers to all applicants, and then used a random number generator to select the applicants who participated in the study. To avoid bias, the subjects were assigned to the groups by assigning each of them a number then used the random number generator to randomly assign the numbers of the subjects to a randomly selected group. In addition, we made sure that none of the subjects had prior COTS selection experience, because such subjects would have expertise that was generally lacking with respect to most subjects.

The subjects were required to select a COTS product for a project that had already been structured by the project manager (the principal author of this paper). Moreover, the alternative COTS products, as well as the grand set of the selection criteria had been identified.

The experiment had three components, namely: COTS selection based on CEP, COTS selection based on CRE, and COTS selection based on the framework for COTS selection. The three components of the experiment were carried out concurrently. Therefore, the subjects were divided into three groups of five subjects, each. The COTS product being selected was meant to solve the problem that was used as an example in Wanyama and Far (Wanyama et al., 2005)[1].

> *In the example, an organization dealing in Chinese food intends to change its business model from delivering food households based upon phone orders to building a webshop where orders can be placed. The system should be able to receive and process orders by telephone, email, SMS, and internet (Web site access). Moreover, it should process credit card payments, and allow for interconnection among outlets so that if a product requested by the customer is not available at one outlet, it forwards the order automatically to the nearest outlet where that product is available.*
>
> *The team developing the software for the webshop intends to use a COTS product to provide most of the functional requirements, then develop the extra requirements and interfaces inhouse. On noticing that the available COTS product alternatives fulfil the same functionalities, the team decides to evaluate the alternative basing on the quality and business concerns of the shop managers.*

In the study, each subject played the role of outlet manager. Table 3 presents the features of the four alternative COTS products from which the managers (subjects) were to select a

Evaluation Criteria	COTS Product			
	Product A	Product B	Product C	Product D
Reliability	1. System is hosted by third party 2. Credit Card transactions are processed by a third party 3. Is used in some web shops	1. System is hosted by third party 2. Credit Card transactions are processed by a another third party 3. Is used in some web shops	1. No Third Party service provider 2. It has used in many web shops	1. No Third Party service provider 2. It is widely used 3. Backs up data
Maintainability	Updates must be compatible with the hosting system	Updates must be compatible with the hosting system	Can be updated through online services	Can be updated through online services
Security	1. The system is hosted by a third party 2. Credit card transaction are processed by the hosting organization	1. The system is hosted by a third party 2. Credit card transaction are processed by a well known card processing organization	1. Runs on owners computer 2. Restrict access but does not track access 3. Utilizes a card processing software that is not well known internationally	1. Runs on owners computer 2. Restricts and tracks access 3. Utilizes ICverfy credit card processing software
Portability	Runs on windows systems only	Runs on windows, Linux and BSD	Runs on windows, Linux and BSD	Runs on windows systems only
Compatibility	Windows 2000 and above	1. Windows NT and above 2. Red Hat Linux 7.0 and above 3. Free BSD4.2 and above	1. Windows NT and above 2. Red Hat Linux 7.0 and above 3. Free BSD4.2 and above	Windows 2000 and above
Vendor Viability	1. Has been in business for 2 years 2. Is not nationally known 3. Is small size organization	1. Has been in business for 5 years 2. Is not nationally known 3. Is small size organization	1. Has been in business for 8 years 2. Is nationally known 3. Is medium size organization	1. has been in business for 15 years 2. Is internationally known 3. Is medium size organization
Initial product price	$149	$549	$995	$1499
Initial Hardware Price	$1500	$1500	$2500	$3000
Implementation Costs	$500	$2100	$1000	$2500
Training Costs	$138	$300	$600	$600
License Conditions	1. 3 months Money back guarantee 2. No license fees	No license fees	1. 5years guarantee 2. No license fees	1. 2years guarantee 2. No license fees

Table 3: Features of the Alternative COTS Products and the Grand Set of the Evaluation Criteria

product to solve the above problem. Moreover, the table presents the grand set of the criteria for evaluating the COTS products. The subjects were required to formulate their preference models by selecting the criteria they are interested in, from the grand set.

5. THE STUDY PROCESS

The subjects under went a forty five minutes training session on how to use the three COTS selection methods. They were also given a questionnaire that they were required to fill at the end of the COTS selection process. Thereafter, the subjects were divided into three homogeneous groups, each with five members (stakeholders). The groups were named after the COTS selection method they were required to employ as follows: CEP-group which employed the CEP method, CRE-group which employed the CRE method, and FCS-group which was required to employ the framework for COTS selection. After receiving all the COTS selection submissions, a follow up meeting was held to discuss the general view of the subjects on COTS selection methods.

The questionnaire that was given to the subjects had the following three components:

- Component 1, which collected information concerning each COTS selection group.
- Component 2, which had statements that the subjects ranked on a scale of 0 to 10 depending to their view of the issues addressed by the statements.
- Component 3, which collected the general comments of the subjects and the project manager.

The following section presents the analyzed results of each component of the questionnaire.

6. RESULTS

This section presents analyzed results of the empirical study on COTS selection methods.

6.1 Results of the First Component of the Questionnaire

Table 4 presents the following information about the three groups, which participated in the COTS selection experiment:

- COTS selection method that was used by group
- The product that was selected
- The average net (working) time the group took to select a product. This is the average of the time the group members spent on the project. For the FCS-group, the average time includes

the extra 15 minutes, which the group required to comprehend the use of the decision support tool that the group used in the COTS selection process

- The gross time the group took to select a product. That is, the time between when the COTS selection processes started (when the training ended) and the end of the selection process (when results were submitted)

Group	Method	Average Time spent on the Process (Net Time)	Period Within Which the COTS was Selected (Gross Time)	Product Selected
CEP-Group	CEP	4.0 hours	32 days	***D***
CRE-Group	CRE	6.0 hours	19 days	***C***
FCS-Group	FCS	1.0 hours	1 day	***C***

Table 4: Time Taken by Each Group to Select the COTS Product

6.2 Results of the Second Component of the Questionnaire

The differences among the COTS selection methods, as well as the users' satisfaction were measured using the statements in Table 5. The questionnaire was designed such that each subject was given statements, which he/she had to award scores between zero and ten. A score of zero meant that the subject does not agree with the statement at all, and a score of ten meant that the subject completely agrees with the statement. Results of this component of the questionnaire were analyzed using two techniques, namely data mining (Berkhin, 2005) and descriptive statistics (Hill, 2005).

Descriptive statistics is the most basic and the most applied form of statistics (Hill, 2005). In the experiment reported in this paper, the statistics was applied to determine the means and the standard deviations of the responses of the subjects to the statements in Table 5. The results of the statistical analysis are also presented in the same table.

Data Mining was employed to cluster the responses of the experiment subjects into groups of similar responses. The primary aim for doing this was to extract patterns in the responses and derive rules associated with the issues addressed by the statements in Table 5. The K-means algorithm (Berkhin, 2005) was used for the clustering process because of the following:

- It is simple to apply
- It is the most well documented and used clustering algorithm (Berkhin, 2005)

Since the experiment involved three groups, we clustered the responses of the subjects into three groups.

6.3 Results of the Third Component of the Questionnaire

Table 6 presents the comments that were made by the subjects and the project manager, as well as the COTS selection method to which the comment is associated. In the table, the source of the comment is the group in which the subject was a stakeholder, the role that the person who made the comment played in the experiment, or the forum in which the comment was made.

7. DISCUSSION OF RESULTS

The results are discussed based on the fact that statements 1-5 of the questionnaire (see, Table 5) address the COTS selection process and the stakeholder (subject) confidence in the product that was selected. Statements 6-9 deal with issues related to the groups the individual stakeholders who participated in the COTS selection process. Lastly, statements 10-14 relate to the COTS selection methods that were involved in the experiment.

No.	Statement	Results			
			COTS Selection Method		
			CEP	CRE	FCS
1.	Your concerns were addressed during the COTS selection process.	Mean	5.0	4.0	9.0
		Standard Deviation	1.9	1.0	0.9
2.	All stakeholders participated significantly in the COTS selection process.	Mean	5.0	3.0	9.0
		Standard Deviation	1.4	1.5	0.7
3.	The product that was selected is the 'best-fit' for all the stakeholders.	Mean	6.0	4.0	10.0
		Standard Deviation	2.9	1.9	0.7
4.	Given what you now know about the alternative COTS products; if given another chance, you would selected the product your group selected.	Mean	7.0	5.0	10.0
		Standard Deviation	2.2	0.9	0.0
5.	You are confident about the product your group selected.	Mean	7.0	5.0	10.0
		Standard Deviation	1.8	1.0	0.0
6.	Your group members were comparative.	Mean	3.0	4.0	10.0
		Standard Deviation	1.5	0.7	0.7
7.	You found it important to know the preferences of others over the evaluation criteria.	Mean	4.0	4.0	4.0
		Standard Deviation	1.1	0.5	0.5
8.	You found it important to know why others preferred a different COTS product from the one you preferred.	Mean	9.0	7.0	7.0
		Standard Deviation	1.1	0.7	0.9
9.	Your group produced documentation that can be used for postmortem analysis.	Mean	6.0	4.0	9.0
		Standard Deviation	2.9	0.5	0.9
10.	It was easy to understand the COTS selection method your group used	Mean	7.0	7.0	7.0
		Standard Deviation	1.9	0.7	0.5
11.	It was easy to apply the COTS selection method your group used.	Mean	7.0	4.0	10.0
		Standard Deviation	2.7	1.0	0.0
12.	The decision support system associated with the method was helpful.	Mean	6.0	4.0	10.0
		Standard Deviation	2.7	1.6	0.0
13.	If given another COTS selection problem you would use the method your group used.	Mean	4.8	2.0	10.0
		Standard Deviation	2.9	2.0	0.5
14.	It is important to use a formal method to select COTS products.	Mean	7.0	3.0	10.0
		Standard Deviation	2.6	1.7	0.7

Table 5: Questionnaire Results

The responses of the subjects of the experiment and the results of the clustering process are shown in Figure 1.

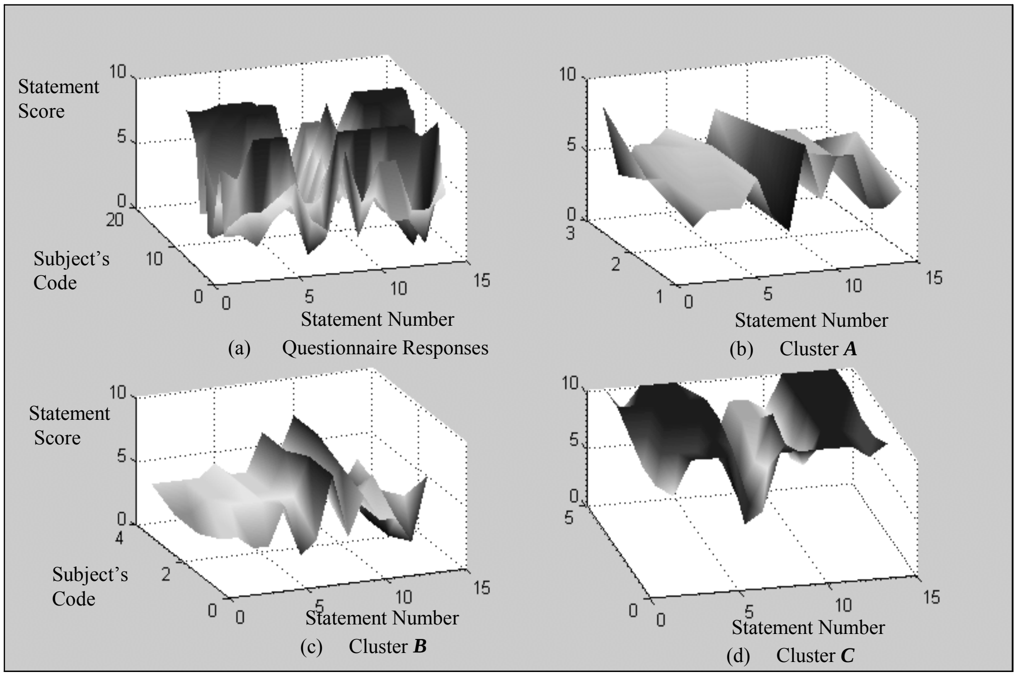

Figure 1: Clusters of the Responses of the Experiment Subjects

7.1 Discussion of Results in Figure 1

The clusters reveal that if a COTS selection stakeholder is satisfied with a particular COTS selection process, he/she is most likely to have a positive attitude towards the COTS selection methods applied, and towards using formal COTS selection methods. However, if a stakeholder is disappointed by a COTS selection method he/she is most likely to employ ad hoc methods in future COTS selection processes than to change to another method.

The spike in Clusters A and B, and the depression in Cluster C at Statement Number 10 shows that simplicity of the process model does not necessary translate into user satisfaction. The rationale being that, over simplification may lead to models that are incapable of representing real problems. In other words, the clusters reveal that users are more satisfied by an appropriate model that requires some time to comprehend, than by a simple model that is inappropriate for the problem being addressing.

7.2 Discussion of Results in Table 4

In this experiment, the performance of the COTS selection methods was measured in terms of stakeholder satisfaction in the process, and in terms of the stakeholder confidence in the selected product. Therefore, the only important information in Table 4 with respect to comparing the strength and weakness of the COTS selection methods is the time taken to select a product that is associated with each method. The long COTS selection time associated with CEP and CRE is not necessarily a result of the features of the methods, but a direct result of the lack of models that address the secondary COTS characteristics that affect the time taken to select products, such as the relative location of the stakeholders both in time and space.

Sources of Comments or Observation	COTS Selection Method to Which the Comments are Associated	Comments and Observations
CEP-Group	CEP	1. The method was quite easy to comprehend and to apply. 2. Some members found it hard to meet regularly, leading to a large gross time for the group. 3. It was very difficult for the group to agree on the criteria weights.
CRE-Group	CRE	1. The method gives no details no how to make the final COTS selection decision 2. The COTS selection model of the method is based on comparing the products with respect to their cost and benefits. When we evaluated the alternative products, we noticed that the products with high benefits were expensive than those which brought low benefit to the project. CRE could not assist in figuring out the best fit product, which was frustrating because this was our key problem. 3. The method was generally unhelpful.
FCS-Group	FCS	1. The auto-mailing system was instrumental in encouraging members to participate 2. It was easy to reach agreement because by the time we met, everybody had simulated various scenarios, and new what he/she liked and/or disliked about each alternative COTS product. Moreover, we had discussed our concerns through email and web-page.
Project manager	CEP, CRE, FCS	1. The CEP-group and CRE-group had problem converting the expert information about the alternative products into quantitative data. The project manager helped them on this issue although their methods had no provision for expert assistance. 2. The FCS-group required an extra 15 minutes training to comprehend the decision support system associated with the method they were required to use.
Follow up Meeting	General	1. It is important for the COTS selection methods to define when they are applicable. 2. COTS selection methods should have associated decision support systems so that when applying the methods, the users can be sure that they are using the right tools. 3. The group DSS of the FCS was very motivating by showing to users the progress being made by their counterparts in the COTS selection process

Table 6: Comments on COTS Selection Methods

7.3 Discussion of Results in Table 5

For the CEP COTS Selection method, the moderate means and the moderate to high standard deviations of the ranking of statements 1 to 5 and 10 to 14 (see results in Table 5) imply that the subjects who used CEP were fairly satisfied with the process they went through to select a COTS product, and with the COTS product they selected. Moreover, the moderate means of the raking of the statements 6-9 reveal that there were some disagreement and dissatisfaction among some the members of the CEP group about the process and the results of the process. Actually, some members felt that they were left out of the process.

The low mean and the low to moderate standard deviation of the ranking of statements 1-5, 9 and 13-14, and the high means and low standard deviation of the ranking of statement 10 for the CRE method imply that there was consensus among the subjects who used the CRE method that although the method was easy to comprehend, it was of little or no help in the COTS selection process. In addition, the low mean and the low standard deviation of the ranking of statements 6-9 indicate that the members of the *CRE-group* concurred that that there was disagreement in the group, on how to carryout the COTS selection process.

Because of the following reasons, it is not surprising that the subjects who used CRE felt that the method was not useful, and that it is not very helpful to utilize a COTS selection method during the process of COTS selection:

- An analysis of the COTS selection methods studies, it was noticed that CRE puts emphasis on requirements engineering for COTS-based software engineering than on COTS selection.

Therefore, it is unfortunate that the method is presented in literature as a COTS selection method, instead of a requirements engineering method.

- The method does not give guidance on how to handle stakeholder conflicts, yet this was one of the major problems that the CRE-group faced.
- The method recommends balancing between cost and benefits of products as a basis for the final selection decision. However, the method does not have a model for determining the balance. Moreover, it does not address the issue of having multiple benefits that correspond to multiple COTS selection objectives.

The low mean and high standard deviation of the raking of statement 14 for the CRE method indicate that the group members generally have a low opinion about the importance of COTS selection methods in general, and that there is a high degree of disagreement among the members over the issue.

The high means and low standard deviations of the ranking of statements 1 to 5 and 12 to 14 for Framework for COTS Selection or the FCS-group imply that the subjects who used the framework for COTS selection were more satisfied with the process they went through to select a COTS product for the problem, and with their selection than those who used the other methods. This is mainly because of the numerous COTS selection support capabilities possessed be the CSDSS associated with this method.

The moderate mean and low standard deviation of the ranking of statement 10, the high mean and low standard deviation of the ranking of statement 11, and comment 2 of the project manager imply that although the FCS method required a little more effort to comprehend than the other methods, it was a lot easier to apply.

7.4 Discussion of Results in Table 6

The comments and observation from the CEP-group reveal that the method decomposes the COTS selection problem clearly and adequately. However, it does not address the secondary COTS selection issues such as information sharing and negotiation support. On the other hand, comments and observation from the FCS-group indicate that providing the COTS selection team with a DSS that facilitates asynchronous problem analysis and processing, hastens problem comprehension and assimilation of information about the solutions, which leads to reaching consensus quickly and objectively. This implies that it is necessary to breakdown the COTS selection problem into multiple smaller problems for easier comprehension and processing. However, without addressing the secondary issues, breaking down the problem is not sufficient to ensure selecting COTS products that satisfy all stakeholders as much as possible.

7.5 Overall Discussion of Results

The experiment results generally illustrate that it is necessary to specify when a COTS selection method works so that prospective users are enlightened upfront on possibility of the method to work in the prevailing project and COTS selection conditions. For example, CRE is a fairly good method for requirements elicitation and negotiation. However, it has limited capability for the purpose of COTS selection. Therefore, it would have been better if the method had been presented as a requirements elicitation method but not a COTS selection method.

Users prefer COTS selection methods which are easy to comprehend and to apply, and which guide them through the COTS selection process. That is, the users become easily disappointed if they get into a dilemma and the method cannot guide them out of it. Moreover, if that happens, they prefer to use ad hoc methods to continue with the COTS selection process, than to employ another formal COTS selection method. Although simplicity of COTS selection methods is desirable, it should not be achieved at the cost of highly degraded capability. For example, the DSS associated with the FCS necessitated extra training for the *FCS-group*. Nevertheless, the group reached agreement much faster than the others.

It is important that a COTS selection method has an associated DSS, so that the users can know upfront the kind of information they need to collect and the results that are expected at the different stages of the COTS selection process. Moreover, the technology of the CSDSS can be used to improve on, or increase the simplicity of the model of a COTS selection method. For example, the DSS associated with the FCS is based on agent technology. This makes it simple to comprehend and to apply, because agent technology has inherent capability to hide complexity. For example, instead of manually moving around information from one application to another, the agents move the information automatically from its source to wherever it is needed.

8. LIMITATIONS OF THE EMPIRICAL STUDY

The case study reported in this paper had the following threats and limitations that could have influenced the results:

- All subjects were students who participated in the study knowing that they were under no obligation to select the 'right' COTS product, meet deadlines, or complete the selection process.
- The selection process did not involve all the possible criteria that could be used to evaluate the COTS products. This denied the subjects the opportunity of applying only those criteria that were important to them. Moreover, it may have made the negotiation process to be very easy.
- It was assumed that the system requirements were complete. Yet in practice, COTS products are selected while the system requirements are still subject to change. This makes the actual COTS selection process to be much more complicated than the selection processes that were carried out in the study.
- Subjects were required to select a COTS product from a predefined set of products which may have made their work easier compared to the actual COTS selection process. Moreover, this denied them an opportunity to search and evaluate products of their own choice.
- We had no access to similar studies with which we could compare and contrast results. This makes the results of the study to be more of a reflection of the capability differences between the COTS selection method that were studied, than a measure of the absolute capabilities of the methods.

On the other hand, we mitigated the effects of the above limitations by ensuring that all the three COTS selection groups carried out the COTS selection process under similar conditions with respect to limitation 1-4. The fifth limitation of the study was mitigated by comparing our method to some of the best COTS selection methods in the reviewed literature (see Wanyama and Far (Wanyama et al., 2005)[2]). Furthermore, we believe that more reliable results could have been obtained if this case study had been carried out in industry over time and under less controlled conditions.

9. CONCLUSIONS AND FUTURE WORK

This paper presented a case study that compares the performance of three COTS selection methods, namely: The Comparative Evaluation Process (CEP), COTS-based Requirements Engineering (CRE), and the Framework for COTS Selection (FCS). In the experiment, the performance of the methods was not measured in terms of the COTS products that were selected; instead, it was measured in terms of user satisfaction and confidence in the results, because COTS selection is a highly subjective process such that what really matters at the end of the process is the satisfaction of the stakeholders. The paper concluded by discussing the results of the experiment, and by inferring the meaning of the results with respect to the capabilities of the COTS selection methods that were used in the empirical study.

In the future, we would like to deploy the three COTS selection methods in industry, and evaluate them through an empirical study. We believe that this shall produce more dependable results.

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