The Challenge of Introducing a New Software Cost Estimation Technology into a Small Software Organisation

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Abstract

Fostering innovation is the key to survival in today's IT business and is exemplified by introducing new technologies and methods to improve the development processes. This paper presents a follow-up case study of technology transfer in a small software organisation. A new software estimation technique, Web-CoBRA was introduced to a small software company to improve their software estimation process. Web-CoBRA was considerably more accurate than the company's current estimation process. However, despite management being aware of this improvement, the company has not fully adopted the new method. We used interviews and the Technology Acceptance Model (TAM) questionnaire to assess the extent to which Web-CoBRA was used by the company. We found take-up of part of the Web-CoBRA technology but the full technology and the support tools were not used. We identify the reasons for the failure to adopt the Web-CoBRA technology and identify several areas for improving technology transfer activities.

Keywords: Software Cost Estimation, Software Engineering, Technology Transition, Web Development

1. Introduction

The primary motivation for this research is to investigate the impact of introducing a new software cost estimation technology into a small software development company. Software engineering researchers have achieved considerable success in improving software estimation accuracy in the last two decades[1], however software companies continue to find it difficult to adopt these methods[2]. As a result, software cost estimation has barely penetrated the mainstream of software engineering [2, 3]. Nevertheless, accurately estimating a new software project early in the development life cycle is still a goal of every project manager.

In late 2001, the Fraunhofer Institute for Experimental Software Engineering (IESE) and the Centre for Advanced Empirical Software Research group (CAESAR) at the University of New South Wales collaboratively investigated the appropriateness of the CoBRA [4] method to predict development effort for web applications in the context of a small software development company.

The research team conducted onsite research for six months, and developed and tailored a version of the CoBRA method called Web-CoBRA. Web-CoBRA was designed to estimate the development cost of web applications in the context of the organisation under study. Members of staff were given a training session once model development was completed. Supporting documents and tools were also developed and introduced to facilitate the new estimation process.

Despite the fact that Web-CoBRA showed a significant improvement in cost estimation accuracy for the company, it was later found that it had not been utilised in practice. Only a subset of the components from the model (i.e. its cost factors) was merged with the company's original estimation method and used to facilitate their risk assessment process.

This paper reports on an attempt to understand the reason for the failure to adopt the new cost estimation method.

The next section presents the background relevant to the study. Section 3 presents the research design of this study and Section 4, 5 and 6 present the results and discussion. Section 7 concludes the paper.

2. Background

IT organisations have enjoyed being part of the most productive and powerful economic sector in the world, but they have encountered intense global and domestic competition in the past 5 years. Software development organisations increasingly experience growing global competition. The demand for better quality products and new management paradigms [5] is proving to be essential for organisations to succeed.

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Quick response and accurate cost estimates are crucial elements in providing competitive bids and remaining competitive in the emerging market environment. According to Porter [6], competitive advantage is achieved through innovation, cost leadership and quick response for customers. Therefore, software process change is inevitable and should, ideally, be based on software measurement programs [7].

Paradoxically, organisations both promote and resist change. IT managers need to know enough about the issues underlying deployment of innovative and emerging information technologies to make rational decisions about putting them to competitive use and leveraging their development process. Because new technology will affect organisations in ways we cannot yet predict, without a set of technology transition management strategies and planning, innovative software products are unlikely to achieve an acceptance from software engineers. That is why technology transition is critically important to the success of software technology adoption and why more work in this area needs to be encouraged.

The Software Engineering Institute (SEI) International workshop on Technology Transition also encourages research and discussion on the use of a Technology Transition Management approach in software organisations [8]. The result is a better understanding of technology transition management and the transition mechanism and key deployment strategies for successful innovation diffusion. In this study, we present a typical real world case scenario where technology and human factors were not considered in the stage of technology introduction, with the result that beneficial tools are not being utilised.

2.1 Initial case study of technology development

The organisation under study is a software development organisation, Allette Systems. It consists of a small core of full time staff that manages and develops software applications. Individual developers and project managers working together communicate informally, and achieve coordination by mutual adjustment [9]. The company has a flat organisational structure that has few management layers compared with the hierarchical multi-layered management structure that typically exist in larger organisations [10]. This is typical of the organisational development of a small start-up organisation [10, 11] This type of organisational structure is typically described as an “adhocracy” , where the working environment is complex and dynamic. Decision-making is spread throughout the organisation, and power is in the hands of experts and developers. Furthermore, managers lack the power to enforce organisational adherence to standards, creating little formalization, resulting in a very organic structure [12]. An adhocracy is usually established to foster innovation [12] and Allette systems is a typical of such an organisation.

In developing and tailoring the new CoBRA model for Allette Systems, the original CoBRA method was first applied and then the model was modified according to the context of Allette Systems by identifying their most important cost factors. Then a qualitative causal model was derived based on the direct relationships of cost factors provided by their experienced experts. Quantifying the relationships within the causal model resulted in a refined CoBRA model, which was later named Web-CoBRA[13].

A cross-validation approach similar to Walkerden’s work [14] was applied to validate the Web-CoBRA model. The basic idea is to use different subsets for model building (training sets) and model evaluation (test sets). Twelve projects were available in the database and each cross validation step used eleven projects as a training set to build a new model and estimate the remaining one project (test set). Thus, a new model is built for each of the twelve training-test-set combinations and the estimates are compared with the actual effort by calculating the magnitude of relative error as a percentage of the actual effort for a project [15]. The magnitude of relative error (MRE) as a percentage of the actual effort for a project, is defined by Conte et al. [16] as:

$$MRE \quad \left| \frac{Effort_{Actual} \quad Effort_{Estimated}}{Effort_{Actual}} \right|$$

And it is one of the commonly used measures to evaluate cost estimation models[16]. In this case, the estimates were compared with the actual effort by calculating the MRE for each project in the data set.

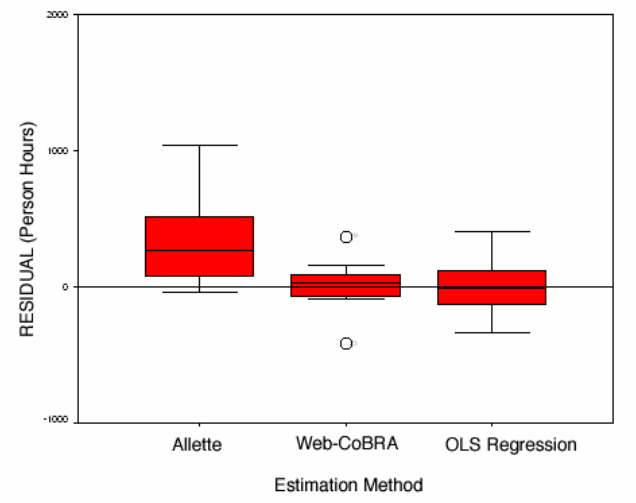

Figure 1. Box plots of the simple residuals (From 12 projects) [13].

Box plots of the estimate residuals (actual effort – estimated effort) are shown in Figure 1. It is clear that the estimation process used by Allette Systems systematically underestimates the effort for web projects. Web-CoBRA and ordinary least square (OLS) regression provide much better estimates. The MRE values for Allette Systems estimate was 0.37 which can be compared with a MRE of 0.12 for Web-CoBRA and 0.23 for the regression model [17].

This analysis clearly indicates that Web-CoBRA has significantly outperformed the company's own task based estimation method, and is appropriate for estimating web application development. However despite this significant improvement in cost estimation accuracy for the company, Web-CoBRA has not been adopted in practical use at Allette Systems.

In the next section, we present the design of a case study to explore issues that contributed to the company's decision not to adopt the model.

3. Research Method

Our research is a single follow-up case study in the context of a small software development company. As is the nature of a technology transfer follow-up case study, we firstly needed to gain a better understanding of the development and implementation of Web-CoBRA, and the organisation involved. It was therefore necessary to use multiple perspectives to explore the technology adoption problem, including technical, institutional and cultural grounds for the company's failure to adopt Web-CoBRA.

The approach taken to explore the impact of introducing Web-CoBRA into Allette Systems was therefore to:

1. Investigate the Web-CoBRA method, and its supporting tools.
2. Determine how Web-CoBRA was introduced.
3. Determine how Web-CoBRA is used.
4. Determine how the users perceived Web-CoBRA.

The majority of the information presented in this paper was gathered through interviews and technology assessments of Web-CoBRA.

3.1 Interviews (Qualitative)

We first collected information through the analysis of Web-CoBRA documents (Table 1).

Development documents
Training materials
Technology Acceptance Model (TAM) survey results
Project data and project staff meeting minutes

Table 1: Table of evaluation documents.

Then, we conducted structured interviews based on the Web-CoBRA documents with both the software developers and the project managers, who are current or former users of Web-CoBRA. The interviews with their software developers reflected their true opinions and attitudes towards the Web-CoBRA method and its supporting tools, while the interviews with their management provided information mostly concerning how the estimation practices were being introduced, and their future development.

3.2 Technology Assessment (Quantitative)

The technology acceptance model (TAM) developed by Davis [18] is a commonly used measure to evaluate user attitudes to information technology. It attempts to assess whether users will accept or reject a specific technology. The TAM theory was originally derived from psychology, being based on Fishbein and Ajzen's [19] attitude paradigm.

The technology acceptance model (TAM) [18] was used to measure the user usage behaviour in the initial study immediately after the introduction of Web-

CoBRA, and suggested very positive user usage behaviour patterns [13]. We investigated whether there was a significant variation in the usage pattern of Web-CoBRA after a 12-month deployment period. Thus, we performed a replication of that TAM survey, where sample data were collected from the same group of the Web-CoBRA users. This allowed a valid comparison of the two TAM results.

In order to avoid confusion, we use "TAM(Alpha)" to refer to the technology acceptance model data collected immediately after the introduction of Web-CoBRA to the company, and use "TAM(Beta)" to refer to the data collected from this follow-up case study.

3.3 Data Collection and Results

Question	Data	Measurement	Result
Is Web-CoBRA used?	Interview	Reported Usage	Zero Usage [#]
	TAM(Beta) survey	Usage rate	Zero Usage [#]
Is Web-CoBRA well accepted?	Interview	Reported acceptance	Unacceptable for general usage
	TAM(Beta) survey	Perceived usefulness	Potential usefulness perceived
		Perceived ease of use	Hard to use
		Predicted future usage	Unlikely
How is Web-CoBRA used?	Interview	Reported most used feature	Used cost factors
What is Web-CoBRA used for?	Interview	Reported use	For risk assessment
What are the effects of using Web-CoBRA	Interview	Reported benefits/detriments	Understanding their cost drivers
What improvements could be made to Web-CoBRA	Interview	Suggested improvement	Improved Supporting Tools

Table 2: Table of evaluation data for this study.

[#] The sample size is small (5), but it represented opinions from 40 percent of overall personnel of the company (12). The participants are experienced software project managers and software developers of Allette Systems.

Table 2 identifies the data we collected to address our research goal and provides a summary of the results. These results are discussed in more detail in the next sections.

4. Evaluation of Web-CoBRA

This section discusses the evaluation of Web-CoBRA and presents the results gathered through the Web-CoBRA development documents and interviews conducted at Allette Systems regarding the use of Web-CoBRA in practice.

4.1 The use of web-CoBRA at Allette systems

From the interviews, it appears that the project managers were reluctant to use Web-CoBRA in replacement of their original task decomposition method. They believed time would have been wasted because developers would have to cope with many new and complicated procedures to produce estimates. Reliability was another concern, since the support technology was not considered mature enough to be used in practice.

4.2 Supporting Tools

Supporting tools to facilitate and automate the Web-CoBRA application process were also developed initially, with functionalities to collect, analyse and report results. They combined several software applications including:

- A web application to capture new project data,
- An Excel spread sheet template for data analysis with
- A statistics package (@Risk) [20] plug-in for probability distribution calculations.

The Web-CoBRA model requires a maintenance step to keep it updated. The experts reported that manually updating newly completed projects was a very tedious job.

The set of supporting tools, including the web front-end, did not take consideration of usability issues [21] [22], and the installation of the supporting tools was only partially completed, as some required components were not available to the company's experts. Thus they found it difficult to use the supporting tools.

4.3 Support and Resource

The two hours intensive training session was reported to be very useful and sufficient for most experienced developers and project managers. However the only supporting documents provided to the developers were a simple Web Object counting reference manual and the training material slides. The creator of the Web-CoBRA model left Allette systems after the development and instantiation of the Web-CoBRA project, although email and telephone contacts were provided. Other software developers at Allette felt they were left behind with no on-going technical support for Web-CoBRA. Implementation of Web-CoBRA was therefore inhibited by lack of support.

4.4 Generalization

Web-CoBRA was designed to specifically estimate the cost of Web applications, in combination with Web object counting [17, 23]. It is therefore not a general solution to estimate different types of projects. As many of the projects at Allette systems involve system integrations, Web-CoBRA offers only a partial solution to the estimation problem. An all-in-one solution was what Allette systems were looking for. One of the project managers claimed: "If it is not something we can do ourselves, then it is not something we can really use."

4.5 Input and Output

In principle, without the intention of using Web-CoBRA for project estimation, it is impossible to gather any Web-CoBRA project data for the long term. Neither has the company kept the Web-CoBRA model up-to-date according to the dynamic changes of the company's environment and cost factors.

One of the important facts discovered in the interviews and described by almost all the interview participants was that Web-CoBRA provides "No Context" information for the output it produces. Web-CoBRA does not allow users to intervene with their own context for the output. "This is typically a black box case, where you can push in a number into the box, and it generates another number without indicating the knowledge of how it was calculated." (Project Manager of Allette Systems)

Without the ability to understand and personally modify an estimate, management had no control over the estimation process. They felt they were losing control over the numbers, when what they really need is a tool that supports decision-making and allows people to apply their own knowledge and context to the estimation activity. This may also have contributed to the usability problem of the supporting tools provided to the company.

5. Evaluation of the Acceptance of Web-CoBRA

The TAM(Beta) survey collected immediately after each expert interview in this study revealed that there was still an overall positive perception of potential usefulness(see Figure 2). There were slight decreases in each of performance, productivity and effectiveness of Web-CoBRA when compared to TAM(Alpha). However, the main measure of usefulness dramatically dropped from 2.67 [TAM(Alpha)] to 0.2 [TAM(Beta)].

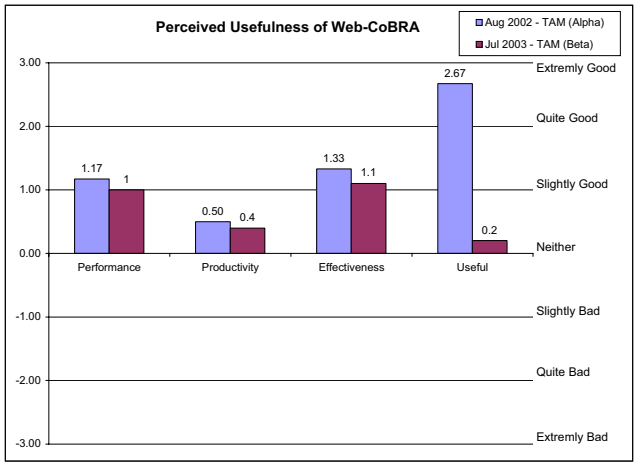

Figure 2. Perceived Usefulness
TAM(Alpha) vs. TAM(Beta)

In measuring perceived ease of use, TAM(Beta) revealed an overall negative perception of ease of use for Web-CoBRA. The rating had dramatically dropped from "Quite Likely" to "Quite Unlikely" when compared with TAM(Alpha) results (Figure 3).

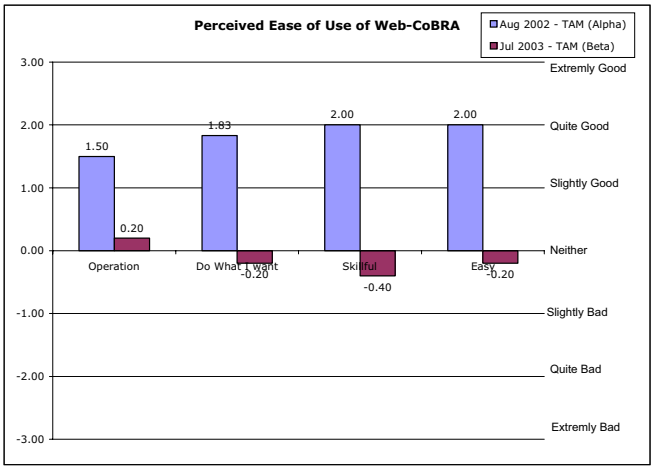

Figure 3. Perceived Ease of Use
TAM(Alpha) vs. TAM(Beta)

The TAM(Beta) survey predicted a low level of future usage and was inconsistent with zero usage for the past twelve months. However, TAM(Beta) revealed a positive level of potential perceived usefulness from the users, it seems the company still has some confidence in the method. The TAM(Beta) result corroborate the reports from the developers during the interview. It is generally agreed the problem may be due to the usability of the supporting tools. But it is not clear why they didn't discover this earlier, before the introduction of Web-CoBRA to the company.

6. Discussion

6.1 Factors affecting technology take-up

In this case study we found that technology transition was hindered by the following factors:

- The Web-CoBRA model only provided a partial solution to Allette Systems cost estimation needs.
- The usability of the supporting tools was poor.
- There was a lack of technical support.
- There was a disconnect between the training and the proposed mode of use.

These factors are discussed in more detail in Table 3.

Factor	Case study results
Partial solution with respect to potential use	Of the 358 projects in the Allette Systems data base, only 12 projects were pure Web Applications. The application of the estimating technique to other forms of project was not considered. In particular, there was no mechanism to allow the expertise of the Allette Systems developers and managers to be integrated with the Web-CoBRA estimate. One of the managers claimed that the approach was "too Black box". Another pointed out that they wanted a decision support tool not a tool that took decisions out of their hands
Partial solution with respect to required functionality.	Allette system's original estimation process was not as accurate as they wished but it did provide a task breakdown that was needed to support staff allocation and project planning. Furthermore it was easily aligned with the company's accounting systems allowing project progress to be easily monitored. Web-CoBRA did not provide task estimates, nor could it be used to monitor project progress.
Support tools were inadequate	The Web-CoBRA support tools were very difficult to use. Furthermore, without use of the tools the Web-CoBRA model cannot respond to changes either in software development activities or in the external environment.
Lack of technical support	After the training action, the researcher responsible for model and tool development left the country

	and could not provide face-to-face support.
Disconnect between actual training and proposed mode of use	The researchers were interested in the use of Web Objects as a sizing measure. Although the practitioners were told they could use analogy for sizing purposes, the training and support tool were oriented to Web Objects.

Table 3 Factors hindering technology transfer

These factors lead to reluctance to use the full technology on the part of managers and developers, although they were able to adopt part of the technology (i.e. the cost drivers) to assist their risk management activities.

6.2 Lesson learnt

The main limitation of our study is that it is a single case study of a specific technology. This limits the extent to which our results can be generalized. However, in terms of general lessons learned with respect to technology transfer, these results indicate that:

- New technologies should be properly aligned with high priority problems.
- New technologies must be well-aligned with exiting processes.
- Support tools must be suitably mature, particularly if the technology underlying the tools requires continual re-calibration to the environment.
- Training activities must focus on the way the technology will be used in practice.

In addition, we believe that one of the underlying reasons for the problems we found with this technology introduction activity was that the technology developer was a research student. The student's goal was to "investigate the appropriateness of the CoBRA method for predicting development effort for Web Applications". In contrast, Allette Systems were looking for a means of improving their estimation process. It is inevitable that researchers and practitioners have different expectations from an industrial research program. Such differences need to be made explicit to ensure that both parties can gain maximum benefit from the research activity.

6.3 Usefulness of the Technology Acceptance Model

In this case study, the technology acceptance model TAM(Alpha) failed to predict the future usage of Web-CoBRA in the company. The TAM model has been used in a large number of technology evaluation exercises and it is, therefore, important to understand why the model failed.

According to Davis [24], the TAM model was originally designed to evaluate user attitudes towards using a technology that they had previously used. It is therefore questionable whether a technology acceptance model is appropriate for predicting future usage of a new technology when respondents have little understanding of, or real experience of using, the technology. This suggests a TAM based technology acceptance evaluation should not be performed immediately after the introduction of a new technology.

7. Conclusion

The work presented in this paper is based on the development of Web-CoBRA [13] and the experience of introducing Web-CoBRA to a small software development organisation. In the initial study, it was evident that Web-CoBRA showed significant improvements in the accuracy of software cost estimation and development productivity. However, in practice, this potentially beneficial method and its supporting tools were not adopted by the organisation.

We identified possible causes for technology adoption failure by interviews with each Web-CoBRA user. The staff member we interviewed also completed a technology acceptance model (TAM) questionnaire to assess the acceptance of Web-CoBRA. TAM questionnaire results were then compared with the results obtained when Web-CoBRA was initially presented to Allette Systems staff.

Although Allette Systems do not currently use the full Web-CoBRA technology, they have found some aspects of use and are still interested in improving their cost estimation technology. We have now developed a tailored software instantiation of Web-CoBRA for Allette call "Artifex". This system is currently under evaluation and we hope it will address many of the issues identified in this research.

This study suggests that, in an adhocracy environment (such as Allette Systems), replacing an organisational process at once is not feasible due to technical and social issues. However the change could be adjusted incrementally. Management should develop a set of strategies to incrementally change the process according to the needs of the organisation. On going support from a technology consultant is critically important particularly in the introductory stage of the transition

In addition there is a need for more work in the area of early prediction of future usage of a technology. The current existing technology acceptance model (TAM) is

not necessary a valid measure for predicting future usage of a technology unless people have experience of using the technology. It is important to evaluate the impact of introducing a new technology into the organisation, and decide on a course of action in the early stage of technology development. It may be possible to use prototyping to support technology transition since prototyping provides a means for end-users to assess technologies at early stages in their development.

Finally, we suggest that when commercial companies participate in joint technology development activities with researchers, the different objectives of the researchers and the practitioners need to be made explicit at the start of technology transition activity. Researchers and commercial companies will have their own objectives and agendas while working together. Therefore, it is important that both parties are clear about their respective roles and responsibilities. This should improve the likelihood of organisations successfully adopting technologies developed by the research community.

8. Acknowledgements

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