Measuring the Impact of Changing Requirements on Software Project Cost: An Empirical Investigation

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Abstract

It is generally accredited that software development is a dynamic process so during the development of a software project many requirement changes are proposed. Literature shows that these proposed changes have the potential to affect the software development in different dimensions. Among these dimensions, cost is major.

This paper demonstrates the impact of a requirement change on the cost of a software project in terms of development effort, i.e. total working hours to implement that change. In our study, a new approach is suggested to compute the effort with the help of Regression Equation. This equation is derived by performing Correlation and Regression analysis on the change request data. The data is collected from nine different software projects of Pakistan's software Industry. Proposed approach is based on a conceptual model for cost estimation presented in this paper. In this empirical study, a systematic impact analysis approach is also discussed to analyze how the impact of a change in requirement propagates from one phase of Software Development Life Cycle (SDLC) to other phases.

Keywords: *Requirement Change, Effort, Requirement Change Attributes*

1. Introduction

Requirement's evolution is mandatory for any software project. Users can propose requirements change at any stage of SDLC. Although change in requirements may affect Cost, Schedule and Quality of a software project [3] but change should be allowable when it is inevitable to meet the customer expectations. Change can be one of the difficulties in software-development [2].

When a change is occurred during the implementation of existing requirements, its impact is not only limited to that particular phase where change was proposed but also propagates to other subsequent phases of SDLC [1]. Because of this propagation effect Cost in terms of development effort is directly affected [6]. Frequent changes in project requirements interrupt the project and contribute to a greater effort each time work is resumed.

This paper demonstrates our findings based on empirical investigation of requirement changes and its impact on Software Project Cost in terms of development effort that is the total working hours of a resource to implement a change. This research study also identifies those requirement change attributes which are the potential factors for the estimation of the effort associated with change by suggesting a conceptual frame work for cost estimation. This paper furthermore discusses a systematic way to analyze the impact of change with respect to a particular phase of SDLC and a generic equation based upon Correlation and Regression Analysis is also derived for cost estimation.

This paper provides information on the related work that has been done in this area (section 2) and then describes the research methodology that has been used to derive the equation for the computation of cost associated with change and the detail description of each step (Section 3). On the basis of the lessons learned from this empirical study conclusion is drawn (Section 4).

2. Literature Review

Bhatti et al [1] analyzed the impact of requirement change with respect to the development phase and reported that more changes are proposed during maintenance phase. Also concluded that changes proposed in requirement phase and changes proposed in design phase have significant relationship and this significant relation indicates that by increase in change requests during requirement analysis phase the requests would also increase in Design phase. Changes proposed in design phase and changes requested in testing phase also have significant relationship and this significant relation depicts that if more changes are requested in design phase then the

changes in testing phase would be decreased.

Zowghi et al [9] defined two types of Requirement Volatility. Pre-SRS i.e. requirement volatility in early phases. Post-SRS, i.e. requirement volatility in later phases of software development life cycle.

Barry et al [7] analyzed the relationship between project duration and project effort by developing and evaluating a two-stage model.

To determine the impact of a requirement change on software development Neal et al [4] presented impact analysis method based on requirement traceability. They created classes of requirement changes by identifying attributes of different work products and traces. Then they prioritized those requirement classes according to their potential impact.

Damian et al [10] reported that there is a positive relationship between improved requirement engineering process and software productivity. According to them a mature requirement engineering process improves overall software development.

To demonstrate the impact of requirement instability on project performance Pfahl et al [11] used the simulation models.

To analyze the impact of requirement volatility on Software Project Performance Nurmuliani et al [6] presented a conceptual Model. In this model they analyzed the direct relationship between Requirement Volatility and Project performance and the impact of other factors. They finally reported that project performance is being measured as the project that is being developed within budget and within schedule and requirement volatility can affect the project performance, and this impact of RV on project performance can be affected by other factors such as organization size and project size.

They also investigated the impact of Requirement Volatility on development effort that is total working hours to implement a change [5]. Their findings reported that if new requirements are added in the later phases during software development it would be a high risk because it will cost the organization in the form of schedule delays or budget overruns. And identified different requirement change attributes that can be used to estimate effort e.g. number of document affected, Source of change and type of change.

3. Research Approach

Fig. 1 describes a novel approach which is used to derive generic regression equations for the computation of the effort as a result of a proposed change.

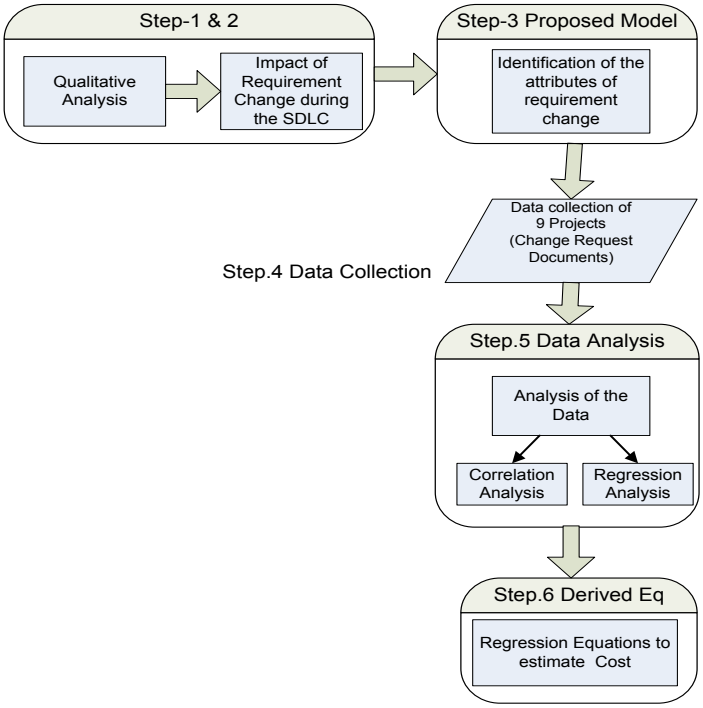

Fig. 1 Research Methodology

3.1 Qualitative Analysis-Research Questions

Qualitative Analysis is the most important phase of proposed approach because it is used to identify the potential requirement change attributes which can contribute to the estimation of the associated cost of change. To achieve this, different questions were asked from the experts of Pakistan's Software Industry. These following research questions guided the research study.

Q1. How changing requirements affect the cost and schedule of software?

Q2. How impact analysis of a change request is performed?

Q3. Which type of requirement change requires extensive rework? (E.g. GUI change, Workflow change, DB change, Process change, Functionality change)

Q4. When change request arises in any phase of SDLC, which work products are affected from it?

Q5. How the effort is measured to implement a proposed change in different phases of SDLC?

3.2 Conceptual framework for analyzing the impact of change through relationship among artifacts.

The conceptual framework describes the different artifacts which are developed in each phase of SDLC and address the second and fourth research questions (Qualitative Analysis). Impact of a change is calculated using horizontal traceability. Fig.2 depicts that to perform the impact analysis of a requirement change, first the SDLC Phase in which change is requested is spotted. Impact of the change is measured on the basis of No. of artifacts to be changed, which depends on the SDLC phase in which change is requested. For earlier phase no. of affected artifacts will be low, while in later phase the no. of artifacts will be greater since more no. of artifacts are produced till later phases of SDLC.

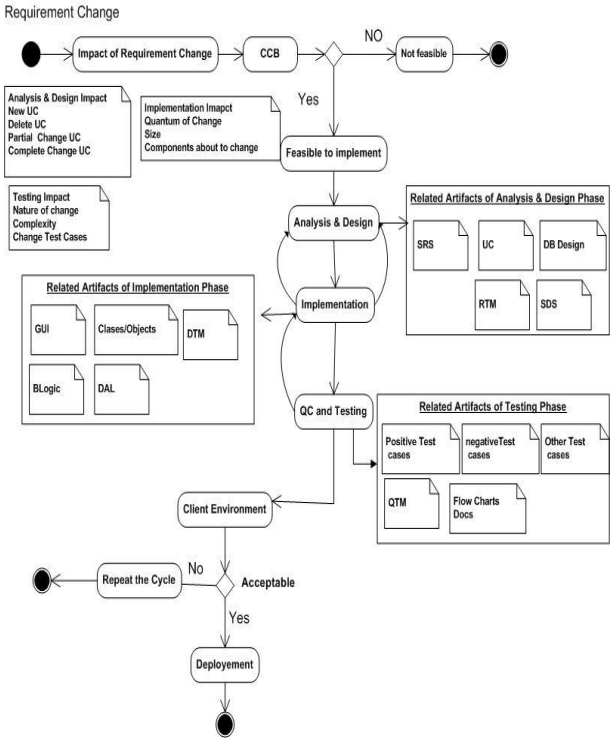

Fig. 2 Conceptual Framework

Frame work also depicts that a change requested during Requirement analysis phase has no chain effect. So only Analysis and Design phase related artifacts which are (SRS (Software Requirement Specification), Use Case Document(UC),RTM (Requirement traceability matrix), SDS (Software Design Specification) , DB Design) would require modification which need less working hours and few number of resources, so computed effort would be low to implement change at this stage. In Implementation phase artifacts related to this phase i.e. (Development traceability matrix (DTM)) and artifacts related to earlier phases i.e. (RTM, DB/Design, SDS, SRS) would need modification so more effort would be required as number of artifacts has increased. In Testing phase artifacts related to this phase i.e. (Quality Traceability matrix (QTM), test cases and artifacts of earlier phases i.e. (RTM, DB/Design interaction (matrix), DTM) would need updation. Traceability Matrices are used to find out size of work (effort) required against a change. This matrix links a requirement to a UC document and UC document to Graphical User Interface and GUI to different classes and objects and links UC document to Test cases. In Maintenance phase the artifacts like RTM, DB/Design interaction (matrix), DTM and QTM are used to find out size of work (effort) required against a change.

3.3 Change request attributes

In this phase, we identified significant attributes of requirement change from change request forms that can be useful in the estimation of effort associated with change. Following are the required attributes

i. Type of requirement change (i.e. GUI, Functionality, Process, Work flow, DB Design)
ii. Software development life cycle phase (Analysis, Design, Implementation, Testing, Maintenance/ Support)
iii. Change Priority (Low, Medium, High)
iv. Number of working hours
v. Number of resources

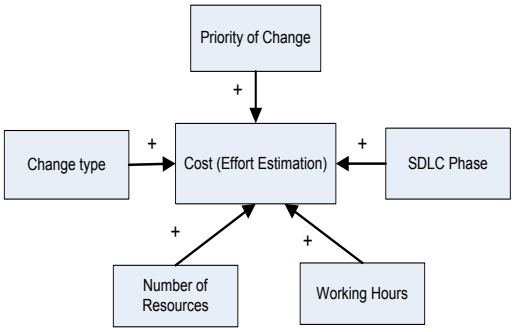

Fig. 3 Conceptual Frame work for Cost Estimation

3.4 Data collection

At this step various change request forms were collected from nine different projects of different organizations. Almost one hundred Change IDS were analyzed against different change request types.

3.5 Analysis of data and Results

Data extracted during qualitative analysis and from change

request forms was collectively analyzed using SPSS software to perform correlation and regression analysis to derive an equation for the computation of the cost i.e. development effort required to implement the change.

3.5.1 Correlation Analysis Results

This statistical analysis shows that the selected change attributes are significant factors for the cost estimation model.

Table 1: Correlation Matrix - Significant factors for the cost estimation model

	Request Type	SDLC Phase	Priority	Man Days Cost
Request Type				
SDLC Phase	-.048			
Priority	.105	.388**		
Man Days Cost	.121	.604**	.620**	

**. Correlation is significant at the 0.01 level (1-tailed).

The statistics of table 1 shows that coefficient of correlation between SDLC Phase and Cost is .604 and this correlation is significant at 0.01 level (1-tailed). This positive relation indicates that if more changes are requested in the later phases of software development life cycle then more effort would be required to implement that change (Fig. 4).

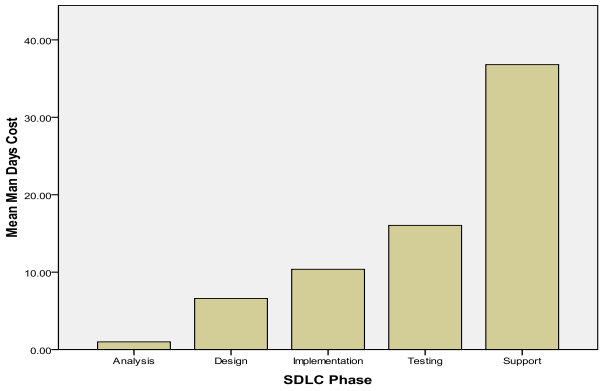

Fig.4 SDLC Phase and Cost of associated change.

This is because if change is proposed in later phase e.g. in Maintenance phase its effect would be propagate to the earlier phases which are, Analysis, Design, Implementation and Testing. As more rework would be required so it would have great impact on the cost associated with change.

The coefficient of correlation between Priority and Cost is .620.This correlation is significant at 0.01 (1-tailed).These results indicate that there is positive relation between Cost and priority of change i.e. a high priority change in requirement results as intensive rework as compare to the low priority change (Fig.5).

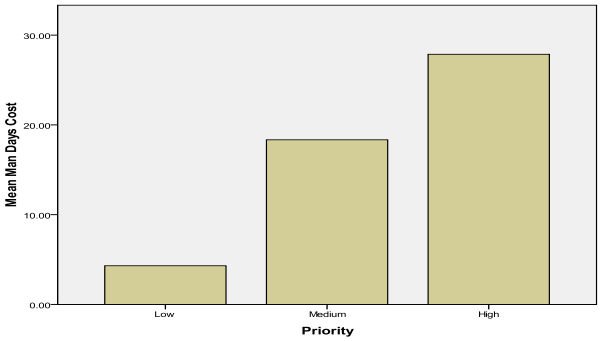

Fig. 5 Priority of Change and Cost of associated Change

The coefficient of correlation between change request type and cost is 0.121.This weak positive correlation shows that up to some extent change type would affect the effort required to implement the change (figure 6).

This is because it depends during which phase Of SDLC change was proposed. If GUI related change occurs in Design phase few rework would be required to make modifications in the related artifacts of analysis and design phase. If same change occurs at testing phase more effort would be required because artifacts related to Testing phase plus artifacts of the prior phases would need modification.

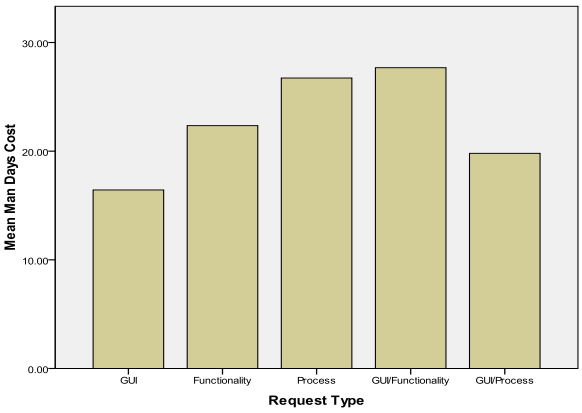

Fig. 6 Request Type of Change and Cost of associated Change

3.5.2 Regression Analysis Results

This statistical analysis shows that Adjusted R-Square is 0.534 and Sig F. change is .000.Which indicates that relationship of Cost in terms of development effort is significant with independent variables Change Priority, SDLC Phase and Change Type at 99.99 confidence interval. This indicates that 53.4 % variance in project cost

is because of these three independent variables (Change Priority, SDLC phase and Change Type).

3.5.3 Regression Equation

Following regression equation is derived by performing regression analysis on the collected data set. This equation is based on the model depicted in Fig.3.

Cost = - 45.967 + 8.605 SDLC Phase
+ 9.784 Priority
+ 1.844 Request Type (1)

Where Cost is the dependent variable and would be computed in terms of development effort i.e.

Effort=Number of Resources*Number of working hours (2)

SDLC Phase is the independent variable and it represents the software-development phase during which change was requested. Coefficient of this variable is 8.60.5

Priority is independent variable and it represents the priority of the requested change. Coefficient of this variable is 9.784

Request type is another independent variable. It represents the type of the requested change. Coefficient of this variable is 1.844

With the help of this generic regression equation (Eq.1) the value of dependent variable that is cost can be predicted against a particular change.

4. Conclusion

In this paper, we have empirically investigated the impact of changing requirements on the estimated cost of the anticipated project. The results drawn during this empirical investigation help to understand how the impact of a particular change in requirements propagates from one phase of the software- development life cycle to another phase. This study has also identified major change attributes, which significantly contribute in estimation of cost associated with change. The momentous relation of change Priority and Cost shows that because of high priority of change, more effort, i.e. more working hours are required to implement that change. The significant relationship of SDLC phase and Cost indicates that if changes are proposed in later phases of SDLC, then more rework is required to implement that change. Our Research also suggests a cost estimation model and a generic regression equation to compute the associated cost of a change.

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