A triangular perception of scope creep influencing the project success

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Abstract: Project management strategies are a part of every organisation as developing high quality customer satisfied software is always one of the challenges for any software organisation. Though the scope creep is known to be one of the factors which influence project success, existing project management strategies do not effectively measure or predict the scope creep. This paper focuses on effective scope creep management which is achievable through a comprehensive analysis of the scope creep and its impact on project success. The paper further presents a case study conducted in one of the leading software companies to investigate the significance and impact of scope creep in the project success. An investigation was carried out on several empirical projects and a three-dimensional visualisation of scope creep on success of project was brought out. This trio visualisation comprises of historical data perspective which leads to visualise the inferences in a pictorial representation perspective. Facts, thus, gained from historical and pictorial data perspectives lead one towards visualisation of scope creep and its management using a mathematical modelling perspective. This mode of visualising the scope creep and its implications on project success ensures one to effectively modulate their strategies in order to develop software products which attain total customer satisfaction.

Keywords: software engineering; software quality; software metrics; scope creep management; total customer satisfaction.
1 Introduction

Evolution of industry has led towards emergence of software. With software gaining its ultimate vitality, all software developing organisations strive towards achieving complete customer satisfied software projects. Thus, project success is the ultimate goal of every organisation. Further, it is proven that project quality and customer satisfaction are the two important factors which measure the project success (Leong and Zakuan, 2014).

Since, effective project management has become a fundamental aspect in the success of the project; it is significant to note that project managers play an important role in ensuring project success. Hence, they incorporate various techniques and strategies to achieve the same. According to the project management triangle, which is popularly followed in all software organisations as one of the modes to ensure project success, has emphasised the fact that scope is one angle which determines the project quality (Toor and Ogunlana, 2010).
Scope creep is defined as inclusion of more tasks than originally specified which leads to higher project costs and possibly variation in estimated project time. Organisations and customers have a long-term relation, mutual acceptance and understanding that the benefits attained by each firm are at least in part dependent on the other firm (Chakrabarthy et al., 2008).

In several situations, change request and scope creep are often viewed as same. However, change request, which is monitored and controlled by the change control board of the organisation, can be anticipated where as scope creep may not be accurately anticipated.

Additionally, Project Management Institute (PMI) indicates that scope management is one of the important areas of project management (Nienaber and Smith, 2009). Scope management typically contains a set of deliverables, an assigned budget and expected closure time. As such, IT industry views uncontrolled scope creep as a major threat for the success of the project.

Due to the above-said reasons, this research motivated us towards analysing the impact of scope creep on project success and its implications. An empirical investigation was therefore carried out in a sampled software industry to understand the aforementioned objective. Initially, this research began by identifying various project success parameters which influence the project success. By further exploring the study, it was possible to categorise these parameters into three categories namely organisation component, human component and technology component. Organisation component constituted parameters such as organisational standards, maturity level of organisation and domain proficiency, determined at organisational level. Human related parameters are such as technical skill set, soft skill set, years of experience, number of developers involved in project. Technology component is a combination of various technology related parameters which include scope, time, cost, software used for development, processing model, project complexity, defect count and customer satisfaction index (Madhuri and Suma, 2014).

Despite several parameters, scope creep is also one of the major factors which directly influence the project success (Madhuri et al., 2013).

2 Literature survey

Due to the significance of scope creep in project success, several researches are in progress to effectively manage scope creep. However, research is also being carried out in all areas that are prone to influence the success which includes project management process, role of project managers, individually analysed project influencing parameters, maturity of the company, process models modulating the project success and so on.

Nair et al. (2011) suggest that various factors such as organisation planning, project control etc are the important factors which help in the effective implementation of project management process. Further, it is always believed that best practices followed in project have a direct impact on project success (Iqbal and Rizwan, 2009). Bauer (2010) opines that an organisation is responsible for implementation of best practices in order to achieve project success. He further states that maturity models enable project personnel
to attain project success. However, Larry et al. (2006) state that for a decade, drastic adoptability of capability maturity model popularly known as CMMI has brought about cultural change in the project development process. The core competency organisation model of Prahalad and Hamel (1990) has highlighted the importance of core competency realisation in an organisation.

Software organisations follow various project management techniques to develop a quality product. It is one of the important techniques to deliver successful projects (Peng et al., 2007). Therefore, domain knowledge, experience and skill of the project manager are very important in making an apt choice of selecting, planning, implementing, monitoring and controlling the project (Kumar et al., 2013). Verner et al. (2005) insist that the project manager is responsible to optimise the use of available resource in the project. As such, technology development phase is considered as a vital stage of the software project (Voas and Miller, 2000). Further, Hanke et al. (2005) have emphasised on technical aspects such as operating system and programming language as important factors to develop a successful software project.

Lu et al. (2014) has investigated and found various project success parameters such as project domain, programming language used, process model of project, time, cost, scope, complexity, defect count, customer satisfaction index etc. According to Verner et al. (2005), accurate success prediction is possible when one adopts a precise requirements management. This is because addition of new requirements has an impact on scope leading to scope creep (Madhuri et al., 2013).

Madhuri et al. (2013) has carried out investigation on several empirical projects in order to analyse parameters that affects project success. They further found that scope creep has an impact on project success too.

Furthermore, a study by Suma and Madhuri (2013) has indicated that impact of scope creep is observed only for those projects which are developed using conventional process approach and that scope creep does not influence projects which are developed using agile process model approach (Suma and Madhuri, 2013). Another work by the same authors in 2014 has inferred that scope creep is one of the major factors for project failure. Additionally, research carried out by Madhuri et al. (2014) has proven with empirical data that scope creep is one of the most influencing factors on project success.

However, research to ascertain project success using mathematical knowledge has also gained its popularity. Woodcock and Loomes (1988) recommend the application of mathematical-based evidences to real problems on an industrial scale. They express that mathematics is the only way through which complexities can be detected and resolved (Forbes et al., 2015). According to the Department of Defense Verification, Validation and Accreditation (DOD VV&A) Recommended Practices Guide, formal methods are based on formal mathematical proofs of correctness and are the most thorough means of model V&V (Brian and Paul, 2013). Reiter (1995) states that mathematical modelling supports two objectives namely:

1. to prove the truth of the research
2. to support the research work through a sequence of mathematical relations.

Henderson-Sellers (1996) states that validity of metrics can be established through mathematical models.
Riguzzi (1996) emphasises that mathematical proof enables one to describe the process by assigning numbers or symbols to attributes such as processes, product and resources of real world entities. According to him, such an assignment preserves intuitive and empirical observations about the attributes. He thus expresses that mathematical model specifies relation between theory and empirical observations.

Research made by above mentioned authors clearly indicate the assurance of project success through project influencing parameters. Further, an effective management of scope creep is found to be one of the most productive parameters which can bring in the expected level of project success. Therefore, this research has focused on comprehending scope creep from three perspectives namely historical-based perspective, graphical perspective and mathematical perspective in order to enhance project quality.

3 Research methodology

Software industries use various strategies to develop quality software. Scope creep is the hitch faced by the project managers very frequently. The change request raised by the customer is acceptable for implementation as the change request are predicted by the manager, but the inclusion of new requirements which leads to scope creep it will defiantly influence the project success.

The main objective of this research is to gain complete awareness of scope creep so that a suitable solution for effective scope creep management can be introduced. Accordingly, CMMI levels 4 and 5 software industries were investigated. This is because change management and scope creep are managed at these levels in companies. Further, the population of projects developed in these companies is yet a challenge. Hence, to resolve this challenge, only non-critical projects were focused for this investigation. Key reason for choice of non-critical applications was that in critical applications, all requests and changes are very carefully death with.

Yet another issue of concern is the domain of non-critical applications to be studied. Since, there exist several domains, this research focused on telecom, retail domain projects which were developed during 2013 to 2014.

Sources of data collection included interviews, face to face communications, mails, data collected from quality assurance departments, defect centres, change control board etc. as per the designed template for data collection. Further information available in technical papers, title research articles, white papers is also considered in this research.

Since, the number of projects developed in industries is a huge population, this research narrowed down to purposive sampling technique where deliberatively CMMI levels 4 and 5 industries were selected. Yet, the population of projects in such organisations is still a universe of data, this research further focused towards collection of sampled projects using selective sampling technique where projects of telecom and retail domain were chosen. This is because such domains are prone to changes and scope creep is more frequent. However, it is once again worth to observe that such domains is having huge number of projects and hence random sampling technique is followed to select few projects for investigation purpose.
Having obtained a large sample of data which were in the range of 200 projects, it was analysed initially to know the parameters influencing project success. Having understood that project success depends majorly on customer satisfaction index, the next step was to analyse all parameters which influence the above stated parameter. This investigation resulted in understanding the significance of scope creep and subsequently its impact on other project modulating parameters.

Above mode of analysis directed this research to comprehend scope creep and its implications using three dimensional perspectives. As such, scope creep is visualised using historical perspective, from the view point of pictorial representations and finally to view the same using a mathematical model. This mode of the three dimensional view of scope creep enables the project team to effectively formulate strategies in order to plan, monitor, control and manage scope creep resulting in customer satisfied software products.

4 Results and discussion

In order to attain a deeper knowledge of scope creep, several software industries were investigated as elucidated in research methodology section. This paper however presents a case study of one of the sampled software industry which is at CMMI level 5. They offer both services and product-based development. All projects sampled in this paper include a collection of banking, financial, telecom, retail domains. They are developed using Ubuntu operating system, Java, J2ee programming language and used Waterfall process model.

A three dimensional visualisation of scope creep is put forth in this paper. Dimension 1 provides a historical view where scope creep and its implications are analysed from the empirical data collected from the sources as stated in research methodology section. In this dimension, initially data is analysed by making a classification of all parameters based on their commonalities found. Dimension 2 provides a pictorial visualisation of the scope creep and its impact on success of the project. This pictorial representation enables one to easily understand the significance of scope creep and hence to formulate effective steps to manage the same. Dimension 3 is a mathematical analysis of the scope creep and its influence on project success. All parameters analysed from above-said two perspectives have led towards introduction of mathematical model to manage the scope creep in projects. This mode of knowledge pod will ensure project managers bring in cultural changes in the project developing environment which ultimately results in producing high quality and customer satisfied software products.

4.1 Dimension 1: Visualisation of scope creep and its impact on project success based on historical data

Upon investigating the list of parameters that influences project success, it was found that many parameters have a commonality and hence could be viewed under one common classification. From this view point, all parameters that were prone to influence project success are categorised. Table 1 thus provides the list of project parameters with their classified category. The table also depicts abbreviations that are henceforth used in this paper for simplicity purpose.
Table 1: Classification of parameters influencing the project success

<table>
<thead>
<tr>
<th>Component</th>
<th>Success parameters</th>
<th>Abbreviations used for parameters</th>
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<tr>
<td>Organisation component (OC)</td>
<td>Maturity level</td>
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<td>Company standards</td>
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<td>Domain proficiency</td>
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<td>Soft skills</td>
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<td>Number of developers</td>
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<td></td>
<td>Years of experience</td>
<td>HCYE</td>
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<tr>
<td>Technology component (TC)</td>
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<td>TCSC</td>
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<td>Defect count</td>
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<td></td>
<td>Customer satisfaction index</td>
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Table 1 thus categorises the parameters under three common classifications namely organisation-based parameters, human oriented parameters and technology driven parameters. This listing and classification of parameters enabled this research to collect data in a structured and systematic manner.

Consequently, data was collected from empirical projects in the aforementioned domain applications and Table 2 illustrates the data populated from the sampled projects. Table 2 further provides information about estimated values for the parameters before the start of the project and actual observational values of the parameters with the completion of the project.

Table 2 indicates a variation of values from the expected to actual in the parameters list. Hence, these variations were computed in order to analyse their percentage of variations as against the initial estimations. Equation (1) is thus used to compute the variations between estimated values as against actual values.

\[
\text{Variation of Factors} = \frac{\text{abs}(\text{actual value} - \text{estimated value})}{\text{actual value}} \times 100
\]  

(1)

Thus, parameters such as scope creep, time, cost, complexity, DC and CSI are evaluated. However, to compute the above values equation (1) is used. For instance, scope creep in telecom project (TP1 from Table 1) indicates estimated value of scope creep by project manager before the launch of project as well as actual value of scope creep after the completion of project. The difference in both estimated and actual value is thus taken as variation of scope creep. This value is now placed in Table 3. Similarly, variations of scope creep values are computed for every sampled project considered. Further, variation of values which is the difference between estimated value and actual value of other above mentioned parameters are computed and populated in Table 3.
## Table 2
Factors influencing project success in retail and telecom domain

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</table>

Notes: RP – retail project; TP – telecom project; PF – project factors; SC – scope creep; ML – maturity level; Stands – standards; DP – domain proficiency; TS – technical skills; SS – soft skills; #Dev – number of developers; EXP – experience of developers; PL – programming language; PM – process model; Comp – complexity; DC – defect count; CSI – customer satisfaction index.
These variation values are statistically significant as they provide a comprehension of pattern of scope creep and CSI impact of the projects in an organisation. Thus, any organisation can foresee from such historical values that when scope creep increases in some range of value, its corresponding impact on CSI and other project influencing parameters can be well-analysed and further predicted for similar such projects.

Table 3 thus indicates the computed variations of parameters using the above mentioned equation. It may be noted that Table 3 indicates projects taken from telecom and retail domains. However, they are arranged in ascending order of increase of scope creep.

Table 3 Variance of factors influencing project success for the sampled projects from telecom and retail domains

<table>
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<tr>
<th>Factors</th>
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<td>12.50</td>
<td>10.53</td>
<td>14.29</td>
<td>5.88</td>
<td>7.14</td>
</tr>
<tr>
<td>VCSI</td>
<td>0.54</td>
<td>1.06</td>
<td>1.11</td>
<td>1.08</td>
<td>2.22</td>
<td>0.43</td>
<td>1.09</td>
<td>1.68</td>
<td>1.10</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Notes: TP – telecom projects; RP – retail projects; VSC – variation in scope creep; Vtime – variation in time; Vcost – variation in cost; Vcomp – variation in complexity; VDev – variation in developers; VDC – variation in defect count; VCSI – variation in customer satisfaction index.

From Table 3 it is evident that there is a variance in the actual and the expected values of the project success parameters. Due to the variations observed, following implications and its associated justifications are drawn.

Implication 1: It can be inferred from all the above randomly sampled projects that CSI is less than the expected value.

Rationale 1: There is scope creep in all these projects leading towards reduced level of CSI achieved than expected.

For instance, consider comparison of projects TP5 and TP1. Both are retail domain projects and complexity variations in both projects are same, i.e., both projects show no increase in complexity. Though all other parameters mention in the table have variations, it is still possible to infer that scope creep has influencing impact on CSI. This is because scope creep in a project indicates addition of a feature or functionality. As such, implementation of added scope demands time, cost also to be increased. However, addition of defect count and number of developers depends on the nature of scope getting added up. Hence, CSI is strongly influenced by scope creep. Thus, scope creep has direct influence on CSI which in turn has direct influence on project success.

Rationale 2: Scope creep and CSI share an inverse relationship.

\[
\text{Scope Creep } \alpha \frac{1}{\text{CSI}}
\] (2)
Implication 2: Project influencing parameters such as time, cost and defect count has increased than expected.

Rationale 1: It is observed for the above projects that scope creep when occurred has proportionally influenced time, cost and defect count.

Thus, cost, time and defect count has direct impact on project success as scope creep influences them directly and hence the project success.

Rationale 2: It can be observed that the scope creep is directly proportional to time, cost and defect count. Hence, stretch factor for these parameters have a direct relationship with scope creep.

\[ SC \alpha time, cost, DC, Comp, #Dev \] (3)

From above inferences, it is quite evident that scope creep acts as a mediating factor between project success and other project influencing parameters. Further, Table 1 also shows technical skill and soft skill values for every sampled project. However, they are not considered for evaluation purpose of scope creep in this part of the work. Hence, it can be taken up as further scope of research.

Figure 1  Graphical representation of scope creep vs. other project parameters (see online version for colours)

From Figure 1 it is evident that scope creep is influencing parameters other project parameters and CSI is influenced by scope creep.

4.2 Dimension 2: Visualisation of scope creep and its impact on project success based on graphical visualisation

The visualisation of scope creep and its implications on project success based on historical information of projects from the sampled company has directed this research to comprehend even better using a graphical representation. Accordingly, the parameters which were investigated were further viewed from yet other perspective namely controllable and non-controllable factors. This is because some of the parameters become
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absolutely non-controllable within a project. Thus, Figure 2 provides a graphical representation of controllable and non-controllable factors which are associated with project success.

Figure 2  Graphical representation of controllable factors and non-controllable factors associated with project success (see online version for colours)

Figure 2 indicates that factors such as maturity level of the company, standards followed in the company, proficiency of domain in which the company has made its name in the market, years of experience of the developing personnel within a project, the programming languages used within the project and the process model other than agile models which is incorporated in the project will never change during the developmental process of that project. Hence, these factors are considered as non-controllable factors within a single project during its span of development life cycle and whose values remain unchanged during developed process.

However, factors such as number of developers, technical skill of the programmers, soft skill, scope creep, project development time, project cost, project complexity, defect count and customer satisfaction index are possible to be controlled and varied during the developmental process of the project. This is because, skill of the programmers may get varied from recruiting new hands into the projects while the project is under development mode, defect count, scope creep also will vary within a project and is not a constant value throughout the project. However, CSI is though predicted to be of some desirable value before project launch, it can still be improved or decreased depending on project influencing parameters such as scope creep, defect etc. Hence, these factors are viewed as controllable factors indicating that by tuning these parameters, it is possible to set the desired level of project success.

Further, from the above visualisations, it was, indeed, possible to redraw the list of parameters influencing project success in a more systematic way. It was observed from the historical visualisation of data that these parameters in turn influence each other in direct or indirect modes.
This analysis is viewed in a graphical mode in Figure 3. Thus, Figure 3 provides a graphical view of hierarchy in which project success can be achieved.

**Figure 3** Project success influencing parameters (see online version for colours)

Figure 3 infers that project success is achieved by both controllable and non-controllable factors. Though, controllable factors influence project success at a highest level, even non-controllable factors which are from the preview of the company, allocation of right type of project personnel, company standards followed choice of process model for the project either be conventional models or agile models also has an impact on project success. This is because it enforces the development team to follow the best practices accordingly and thereby leading the process to be success driven.

Further analysis on the graphical visualisation based on historical information has brought out yet another view of project success. Accordingly, project success is decided based on customer satisfaction index. However, from the data analysis, it is found that customer satisfaction index is in turn decided by several other factors among which, scope creep has the maximum influence. Thus, Figure 4 shows the influence of project success in a layered approach.

**Figure 4** Influence of project success in a layered style (see online version for colours)

The graphical representation of project scope in Figures 4 and 5 indicates that project success is from the customer satisfaction index. However, customer satisfaction index is further influenced by controllable factors. Though, controllable factors operate within the non-controllable project environment. Further, controllable factors within an organisation
drive the development team to redirect their skills and process towards generation of customer satisfied software products.

**Figure 5** Cylindrical view of project success (see online version for colours)

**Figure 6** Scope creep which is associated with all parameters and their performance in project success (see online version for colours)
Figure 6 depicts that scope creep is one of the major parameter which influences customer satisfaction index. This analysis was obtained from Figure 4. All the above claims are made in concurrence to historical view what was made and presented using sample projects from Tables 1 through 3 in association with inferences drawn from them. Proceeding further, from the historical information obtained from all the studied projects, it is evident that scope creep not only influences customer satisfaction index but also influences other project influencing parameters. Hence, this understanding leads towards relation existing among all parameters with scope creep either directly or indirectly.

4.3 Dimension 3: Visualisation of scope creep and its impact on project success based on mathematical modelling visualisation

The third dimensional view of influence of scope creep in project success is through mathematical model approach. A mathematical model is an abstract representation of the system using mathematical language. This model enables one to describe the properties of a system by providing an accurate explanation for the observed properties. It provides systematic and scientific solution to a problem.

As per the inferences in Section 4.2 and equations (2) and (3), it is clear that scope creep has an impact on customer satisfaction. From historical data and from pictorial representations, it is apparent that project success is determined by customer satisfaction index which in turn is decided by several parameters. However, among the list of parameters, scope creep was found to have a major impact since scope creep by itself influences other project modulating parameters. Therefore, a third dimension of visualisation includes mathematical representation since it is found that there exists some form of relation between scope creep and other project influencing parameters.

Moreover, the historical data has proven that all parameters are not exhibiting similar relation with scope creep. This is because some are directly proportional to changes in scope while some parameters get affected inversely with scope creep. However, there are projects where certain parameters have at times being influenced while many times remains unchanged with scope creep.

Thus, from the mathematical perspective, the model which can be thought to be apt in such situations is regression model.

Regression analysis is the best way to fit straight lines to patterns of data. In a regression model, the variable of interest or dependent variable is predicted from k other variables which are also called as independent variables using a linear equation. If \( Y \) denotes the independent variable, and \( X_1, \ldots, X_k \) are the dependent variables, then the assumption is that the value of \( Y \) at time \( t \) (or row \( t \)) in the data sample is determined by the multiple regression equation.

This research therefore enabled to view implications of scope creep on project success using multiple regression models (MLR) since there are multiple parameters which are in turn affected due to scope creep. An MLR model consists of a set of constants which are also called as process coefficients.

The multiple equations for scope creep and success parameters is

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7
\]  

(4)
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where

$Y$ scope creep
$X_1$ project cost
$X_2$ project time
$X_3$ number of developers
$X_4$ defect count
$X_5$ complexity
$X_6$ technical skills
$X_7$ soft skills

$\beta_i$ coefficient

$\beta_i$ is the weight which indicates its impact due to scope creep.

Further, it may be recalled from Tables 1 through 3 and their inferences drawn using dimension 1 that CSI is directly proportional to scope creep. Hence, deciding the extent of scope creep allowable for a project within organisation enables decision of CSI level. Thus, output of regression model acts as an input for organisation to decide their degree of CSI.

Thus, this research has put forth a three dimensional visualisation of scope creep and its implications on project success. This paper has provided a comprehensive view of scope creep and further work will provide a detailed view of mathematical visualisation and its validation.

In historical perspective, data is collected from previously developed projects (empirical projects) where the main intention is to check if the project success which is dependent of customer satisfaction is dependent further upon scope creep or any other parameters. However, from statistical analysis though one can ensure the customer satisfaction influencing parameter in the form of values, yet a visualisation of the same via diagrammatic representation is always easy to comprehend. Therefore, objective of second perspective is to visualise the success of project using only list of parameters in the form of project modulating factors list. Further, mathematics ensures preciseness of the concept. However, it is further proven from historical perspective that project success is determined through CSI which is modulated by scope creep. Hence, to emphasise on the correctness of the proof, mathematical visualisation is considered and approach for the same is put forth.

Further work is encouraged to introduce metrics to measure scope creep.

5 Conclusions

Due to the significance of software in day to day activities, developing high quality software has become one of the essential goals of software developing organisations. However, due to inconsistencies and dynamic nature of requirements, scope which is
initially formulated to develop any software project undergoes inclusions. This mode of scope creep during software development process has impact on success of the project. This research therefore focused towards identifying the implications of scope creep on project success. A case study is carried out on empirical projects drawn from a leading software industry in order to understand the aforementioned objective. The data thus obtained has led towards visualising the implications of scope creep in three dimensional perspectives namely historical visualisation, pictorial visualisation and mathematical visualisation of scope creep on project success. Trio way visualisation of impact of scope creep on project influencing parameters and further on project success will enable project managers to formulate strategies towards effective management of scope creep. This in turn leads towards customer satisfied software projects and sustainability of the software company in the global market.

References


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