Factors that Influence Software Project Cost and Schedule Estimation

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***Abstract*— Software Project Management is a core topic in software engineering courses because it teaches how software projects planned, implemented, controlled, monitored, and evaluated. The development of theories in software metrics and prediction models builds on the broader project management field but also attempt to overcome the difficulties inherent in measuring an intangible object like software. This paper is situated within research into the factors that influence cost and time estimation for software projects that continue to challenge software development organizations. The study described in this paper explored technical and non-technical factors seen by Sudanese software practitioners as critical in estimation, and if not managed, can result in cost and time overrun or in some cases lead to project failure. Using a mixed-method approach, the research project was first informed through a qualitative study that explored the kinds of problems that face the estimation process from the perspectives of different staff levels. This part of the study revealed a number of factors that can be broadly categorized as technical factors, e.g. the skills of those involved in the estimation process, and non-technical factors such as the high level of uncertainty in the local business environment. The second part of the study focused on one of the leading factors, software project staff training and experience, using the survey method to examine how well the software engineering curriculum is aligned with skills required in the software market, especially those related to estimation. The recommendations this study produced on reducing estimation errors, whether geared towards companies or academia, are preliminary and may only reflect the local setting. However, they also drew upon the vast literature on cost estimation techniques and case studies in similar and more advanced settings. The problem of software effort prediction and estimation models has been a thorny issue in the software engineering field since the concept of "software crisis" and the field itself, as a response to the crisis, emerged in the late 1960s. It still seems to some that "*After forty years of currency the phrase 'software engineering' still denotes no more than a vague and largely unfulfilled aspiration*" [2]. This study develops our understanding of problems facing one of the young professions in the country, as well as contributes to the global body of research on developing techniques to manage the intricacy of software engineering compared to more established engineering disciplines.**

Keywords*— *Software Project Management; Software Effort Prediction; Software Project Failure; Software Project Cost Estimation techniques

I. INTRODUCTION

Project management is the application of knowledge, skills, tools and techniques to different activities undertaken to meet the project requirements [1]. The project management process, at base, is about balancing project scope, time, and cost goals. Not only this is the most challenging tasks in software project management, but is the most crucial to the organization's capability to plan the software development process and allocate the required resources. Project managers, who often use formal project management tools (e.g., Brainstorming, Fishbone Diagrams, Critical Path Analysis Flow Diagrams, and Gantt Charts), see that they allow better control of financial and human resources. They regard the feedback loops in these tools as beneficial to customer relations, and that the metrics incorporated measure the development process and help to improve the organizations' performance towards shorter development times, lower costs, higher software quality and reliability, and higher profit margins.

There is a number of software cost estimation methods proposed to predict the effort required for software development. Still, a large percentage of overruns in estimation are reported, and a range of factors that influence software development process and causes overruns are highlighted. For instance, Standish Group in 1994 found that approximately 31% of corporate software development projects were cancelled before completion and 53% exceeding nearly double their original cost estimate [3]. The Group's more recent report in 2015, about contexts that predominantly have a highly developed software profession, indicated that there is still work to be done to improve cost estimation [11].

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This paper is structured to give an overview of factors that influence software project estimation that are reported in the literature in the next subsection. The third section describes the software development context in Sudan where the research was conducted. This is followed by the design of the study reported in this paper. The remaining sections (5 – 8) present the findings, discussion, and recommendations that came out of the study.

II. RELATED STUDIES

The studies that study estimation problems and software projects failure reasons found that projects generally fail because of poor planning, poor communication, undefined goals, and constant changes in the project's scope, and therefore, deadline and budget, as well as the lack of monitoring and control during project implementation [4,5,6]. In addition, insufficient skills of project managers and poor communication, within team and with customers, were considered as important factors in project failure or overrun. More recent research that investigated poorly estimated software projects and explored the factors that influenced the estimation process and were behind the projects' failure [5, 6, 7], found a myriad of issues that intervene. They are summarized below thematically: as mentioned in [16].

Management: Top management commitment determines the tipping point between potential success and failure when developing and implementing business management projects and systems. Clarity of project goals and objectives were seen as influential in its success.

Project Design: The design provides an account of the project in its entirety, while the plan focuses on the operational perspective that directly deal with uncertainty and has impact on the estimated cost.

Communication: Problems in co-ordination and communication that should happen throughout the development life cycle are a major factor in the delay and failure of software projects. Lack of customer or user involvement can lead to unrealistic expectation and become a source of failure.

Staff Experience: Staff weaknesses, lack of commitment, and turnover of qualified staff, are among the leading factors that influence the estimation process.

Funding Problems: Project finance often experience delays, and is mainly due to poor cash flow management, but also can come from late payment, insufficient financial resources, and general economic instability.

Price Change: Pricing, in the most part, does not take into account the broader organizational, economic, political and business considerations, such as market opportunity, financial health, requirements change, etc. can contribute to the derailing of the project.

Technical Factors: In some projects, the use of inappropriate estimation tools played a role in the project overrun, and in others, regulatory cost estimates were found to have ignored the possibility of technological progress.

In developing countries, the estimation process faces greater challenges because many companies follow in-house standards and their clients are less versed in software capabilities, and often expect additional features that are not part of the contractual agreement or are unable to describe the requirements clearly [13]. A study of software companies in Saudi Arabia, found that small companies (which are more prevalent) to usually not use any estimation methodology or follow a development methodology which is mainly due to lack of expertise and guidance or because of cost and time learning the tools would entail [17].

A Kenyan study that proposed a framework for risk management adoption for software projects found out that software problems come from two major areas, software engineering institutions and software development industry [14]. In the case of software engineering institutions, the study argues that they fail to emphasize software management, which includes estimation concepts and tools, in software engineering courses, and therefore produce employers who lack basic knowledge of project planning and management. On the hand, the software industry contribute to project failure by using ad hoc, unstructured and undocumented management approaches. There is a wide agreement that many

organizations do not consistently apply existing approaches for software development excellence [13, 7]. In spite of several problems experienced by Kenyan software managers and developers, the perceived root for these problems include; lack of awareness, undefined policies, poor motivation and lack of proper training in the area of risk management [12]. The pattern is similar in developed settings where a study of software development firms in New Zealand [16] showed that the majority lack proper communication of risks or do not manage risks all together which led to repeated problems and compromised the quality of software they produce.

III. THE CASE OF SUDAN AND THE NEED FOR THIS STUDY

Software companies in Sudan are also challenges by the process of software cost and time estimation. A relatively old survey study in 2001, found that 75% of software projects in the sample have failed because of lack of time than for all other causes combined [15]. The study identified problems of scheduling where the researchers found that schedule estimates are not assessed in terms of compatibility with the project size, not monitored during development to account for changes, and do not draw from past projects experiences. There are no similar recent studies. Reflecting on Sudanese context, found in the literature, which highlights the importance of the study reported in this paper.

As can be drawn from global, regional and local experiences with software project estimation, there is no one overriding factor that causes project failure or overrun, a number of factors are involved in any particular project failure, some of which interact with each other. Overruns in cost and schedule are commonplace, however in developing countries they can be described as more acute. Drawing from the personal experience of the first author who worked for a number of years on different software projects of varying sizes, none of these projects was completed on time, nor were their schedule and budget clear (or even set) at the start of the project. An experience that is not uncommon among local software developers. Despite the increasing number of universities offering software engineering courses and software development companies, there is little updated research that focus on the problem of estimation and or on the factors that influence project cost and schedule estimation in Sudan. This study attempts to provide an updated picture of overruns and their causes in the local software scene.

IV. THE STUDY DESIGN

The study adopted a sequential mixed method approach to first explore the problems that software practitioners see in the software project estimation process from their lived experiences using open-ended questions and interviews with different categories of those who are directly involved in the software development process (e.g. project managers) and those are indirectly involved (e.g. academics). The overarching question of the qualitative part of the study asked participants to discuss *"what they think are the factors that influence the accuracy of software project estimation in Sudanese software companies?"* This question was accompanied by a list of factors that were summarized from the literature to investigate the similarities and differences with other contexts. The interviews with participants were either conducted in person, or via phone or email.

The first set of participants came from small to medium software companies (private and governmental) that are based in Khartoum, and their work directly contributes to the cost estimation process. They included general (or top) managers, project managers, and senior developers. Another set of participants, who either directly or indirectly affect the estimation process, were also interviewed. This set included the categories of customers of software companies, policy makers who develop the regulation that govern the professional relations between the two, in addition to academics who design the courses that equip students with the required skills.

The sampling technique followed a purposely selected set to ensure that only participants who have at least one year experience with software estimation, academics who taught software project management, or policy makers who developed

relevant policies, customers who have bought more than one product, are included. Follow-up (half an hour) interviews were conducted with a small number of participants who were considered as experts (2-3) from each category to gain more understanding of their views and discuss the gathered information. Table (1) lists the total number of participants in each category

Table 1 Participants in Qualitative Study

Category	No. of Participants
Project managers	6
Academic Staff	6
Senior Developers	3
Customers	3
Policy Makers	2

The information gathered from this part of the research project, indicated that the training and experience of project managers and software developers is one of main factors that influence the estimation process. The decision to pursue this specific factor through a quantitative study, as opposed to choosing other important factors such as the instability of the business environment, was made for various reasons. The first is to focus the project on a software engineering issue, and second, to focus on a problem that can be regarded as the base from which software engineering emerge to the business environment. In addition, the researchers' context as academics, allow for investigating and making relevant recommendations as well as informing the researchers' own teaching methods.

The quantitative part of the study used a survey method to investigate the student's understanding of core project management concepts and estimation process and tools, to explore theirs views on the training provided, and how they assess their capability to estimate the needs of a software project. Participants were drawn from B.Sc. and M.Sc. students who attended a software engineering course at the Faculty of Mathematical Science, University of Khartoum. For undergraduates, only students in their final years (fourth and fifth), i.e. after they have been exposed to advanced software engineering topics like cost estimation. For postgraduates, the most recent (i.e. accessible) M.Sc. batches (2016 and 2017) were included. The purpose of including two categories of students is to examine if there is any difference in assessing curriculum between students before (i.e. only based on classroom learning) and after graduation (based on both concepts and application). The sampling was random by sending the survey questions to all students in the selected years. Table (2) lists the number of responses in the different participant's categories.

Table 2 Participants in Quantitative Study

Participants Level	No. of Participants
M.Sc. Year 2016	20
M.Sc. Year 2017	25
B.Sc. Final year	18
B.Sc. Fourth year	22

V. ANALYSIS AND DISCUSSION OF QUALITATIVE STUDY FINDINGS

This section discusses the findings of the qualitative part of the study that explored the factors seen as influential by different stakeholders in the cost estimation process. The factors are clustered in the first phase of the analysis to identify the broad or strategic areas that are important to improve the estimation process. The second part of the analysis clusters the factors in terms of their importance to the different stakeholders. This analysis can similarly reveal a possible improvement that can be beneficial to more than one stakeholder.

The interviews identified internal and external factors, that is, whether it emerges from within the software project or company, or affects the project from outside the company. The following two subsections present the factors in clusters, and their distribution among the categories of stakeholders. The final subsection compares and validates the findings from this study with related research.

A. Factors in Clusters

The factors clustered into five broad categories that are further split into subcategories (see Fig.1). The top level includes political, cultural, economic, technical, and administrative factors.

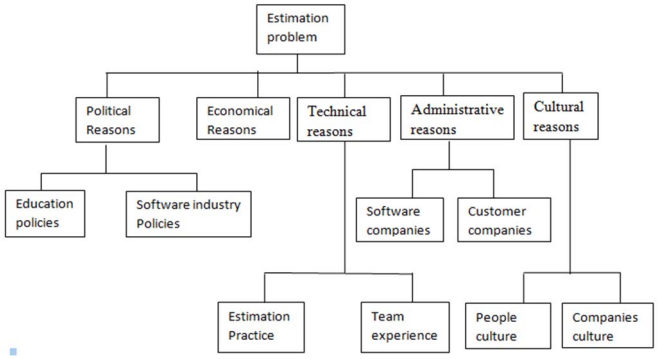

Fig. 1. A Hierarchy of Estimation Factors

In the broad sense, companies can use this hierarchy to locate problems which is the first step to solve it. The categories can also help educators to structure and address these issues in class examples and coursework. The figure suggests that the solution space consists of more than cost estimation techniques. Seen from different perspectives, a broad understanding of issues involved, as attempted in this diagram, is important to improve estimation practice and training. The next subsection explores the problems seen as important from different vintage points.

B. Factors and Stakeholders

The broad classification generated in the first step of the analysis of the findings is expanded in this subsection to highlight their importance to specific categories of stakeholders. This analysis can reveal common issues seen as important by different stakeholders. For example, policy makers mentioned difficulties in the institutionalization of policies as an important factor that influence estimation process, a problem of a political nature. On the other hand, the academics saw management commitment as a key factor that can be classified under administrative problems and project management practice in companies. In Table (3), the factors presented in their top-level categories, and listed according to the category of participants in the study to whom the factor matters most.

Table 3 The Relationship between Categories of Factors and Participants.

	Policy makers	**Academic staff**	**Customers**	**Project managers**
Political reasons	-Policies institutionalization (no local standards).	-Poor organization policies		-Political pronouncement
Economical Reasons		-Budgets problems	-Dollar price disruption	
Technical reasons	-Lack of practice and training on software management	-Lack of practice and training on software management	-Lack of consideration to the customer needs	-Lack of documentation -Design change
Administrative reasons	-procedures depend on the persons running the organization.	-Management commitment.	-No management support. -Instability of process -Instability of authorities -Poor planning	-Lack of project team involvement
Cultural reasons	-Business culture in software companies is not prevalent.	-Work cultural issues,-Lack of accountability and motivation	-Employee resistance	-Unclearness of development process,-Work cultural issues

C. Discussion

The factors that emerged from this study largely agree with those reported by Linberg [8] who examined why projects fail. Of Linberg's thirteen factors, this study agree on nine of them with minor naming differences. The factors that are common between the two studies include underestimated project scope and poor understanding of it; frequent change in software requirements; political issues; management factors, conflicts between projects, inexperience of project managers, inadequate software team involvement; unrealistic schedule; and budget constraints or lack of resources. While Linberg did not give details about the types of political issues and how they influence estimation; this study defined this category of factors as related to the company's policies issues, and to national policies.

On the other hand, this study partially agreed with overrun factors reported in [7] that highlighted both poor estimation practice, and no practice, contribute greatly to project overrun. The factors identified in [7] include the use of new or complex technology that can also affect the estimation accuracy, but this issue did not arise in this local study because the problems leaned more towards poor implementation of estimation practice or no estimation practice, rather than the effects of the use of complex methods.

Rajkumar and Alagarsamy [9] studied the common overrun factors and listed a number of them. This study concurs with the impact of communication and technical factors, lack of customer or user involvement, lack of resources, as well as project planning and scheduling. Additional factors emerged in the local study, such as the lack of risk assessment and management, lack of project documentation, software developer's turnover, and software company structure.

The findings of this local study, corroborates similar studies such as the three factors identified by Egbokhare [10], namely, the incompatibility of estimated schedule with project size, the lack of monitoring of schedule during development, and more notably, the absence of documentation procedures of projects that can help in prediction of resources required for new projects.

Sudan, a developing country and the focus of this study, is not removed from the global software industry. Previous research [15] identified three factors that also emerged from this study, two of which agree with [10] on the problems of considering project size and monitoring project progress. The third is the lack of historical databases of software projects, identified as an influential factor, in [15] and this study.

VI. ANALYSIS AND DISCUSSION OF QUANTITATIVE STUDY FINDINGS

At this stage of the research project, the study focused on the t raining and experience factor that was highlighted by the quali tative inquiry into factors influencing cost estimation that gath ered information through interview with different stakeholders . This quantitative study constitutes the small part of the resear ch project where two different questionnaires were distributed to B.Sc. and M.Sc. students to explore influence of project ma nagement course on cost and schedule overrun.

The questionnaires collected data about project management curriculum which classified into items related to project management curriculum, practice and training and items related to course instructor. For M.Sc students, years of experience was added to test if any significance between experience and inexperience students evaluation.

The survey responses were analyzed using SPSS and R tool. The results showed (Fig.2) that the students were satisfied with the curriculum and thought that the course instructors were effective in imparting the concepts taught. While this indicate that there is no problem with the instruction process, Fig.4 highlights that there is a problem in application of learned concepts.

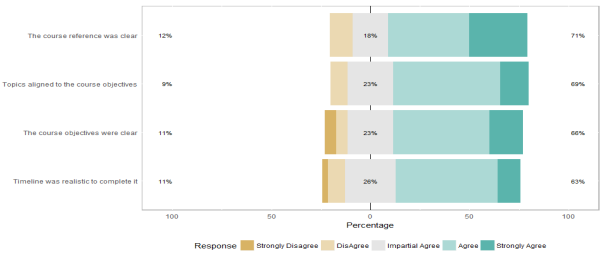

Fig.2 Project Management Curriculum Evaluation

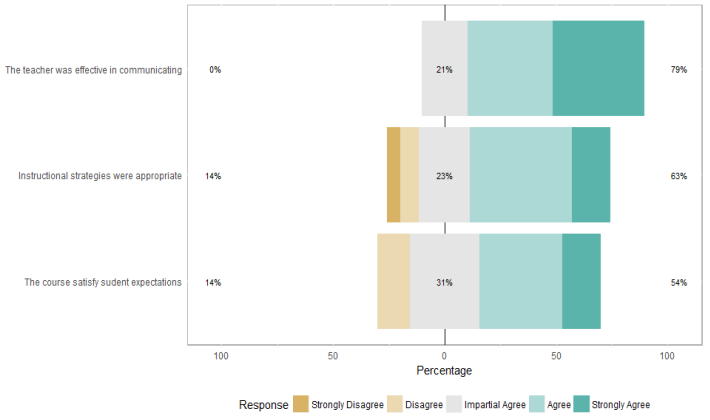

Fig.3 Instructors Evaluation

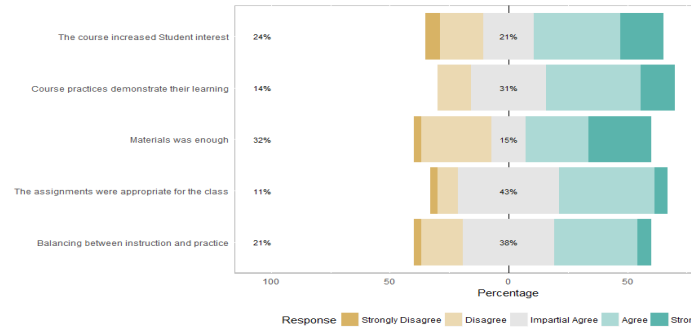

Fig.4 Course Assessment and Practice Evaluation

The agreement percentages about course assessment and practice range from 41% to 55%, which may indicate that there may be problem in course practice. For more clarification we used wilcoxon test to test if any difference between M.Sc and B.Sc. levels or any relation between years of experiences and participant answer, and also testing if there were a significant difference between the answering tendencies of Males and Females, and tendencies of B.Sc and M.Sc. The wilcoxon test indicate that there is relation between years of work experience and participant answers.

Males seem to have a higher tendency to agreement with the assertion made for balancing between instruction an practices as the agreement, Females seem to have a higher tendency to disagreement and neutral(impartial agree) with the assertion made.

Also about balancing between instruction and practice we saw some differences between M.Sc and B.Sc students as well as male and female, figure below show males in M.S.c level have a higher tendency to strongly disagree

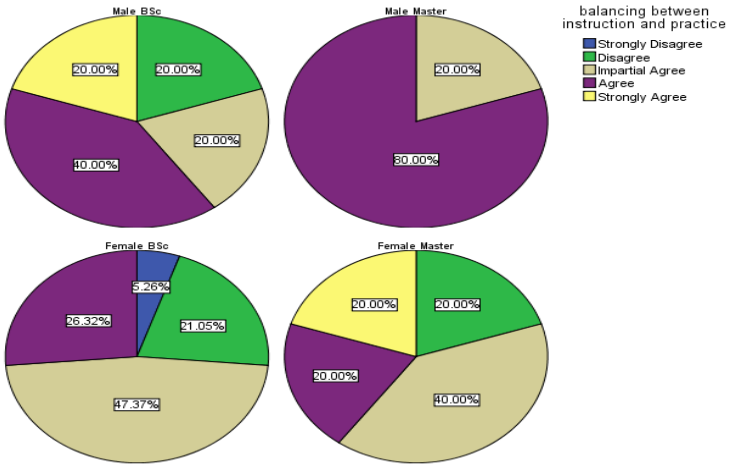

Fig.5 balancing between instructing and practice

VII. MAIN RECOMMENDATIONS

This research highlighted five main influences on project failure in Sudan where improvements can be made in order to provide more accurate project estimates. Based on these findings, and informed with findings of similar studies, the following recommendations were drawn:

A. Recommendations for Development Companies

This category can provide parts of the solution by employing a system of feedback processes to conduct cost and budget analysis and determine the areas where there is a risk of inaccuracy. These areas, once identified, can be amended to the pricing structure to correct discrepancies. The feedback system could be used to train junior developers or junior project managers in exploring past mistakes, discrepancies, inaccuracies, factors for estimation, and estimating methods.

B. Recommendations for Policy Makers

Encouragement to the local software industry is highly recommended, in addition to the need for developing standards that fit to local context and take into consideration local practice.

C. Recommendations for Academics

The participation between software companies and universities, can potentially improve students' skills, and ultimately, local practice. Companies can engage in the educational process by providing real project cases that students can learn from before facing them first time in the field.

VIII. CONCLUSION

Software cost estimation is a critical process in software developments that inform decision-making of project managers and enable the success of software projects. This paper highlighted factors that influence software projects management and sometimes cause the failure of a software project, in particular the paper focused on cost and schedule overrun that are important for software project estimation theory and practice.

The findings from this study show that software development projects in Sudan face similar challenges to the global scene. Because the software development profession is still young in Sudan, like most developing countries, software project failures are caused by both technical and non-technical factors. Lack of adoption of software engineering practices (project management factors) and poor human level interactions and organizational politics (organizational factors) are the major causes of software development failures in Sudanese software development companies. Moreover, the study found that lack of definition of roles and responsibilities in software projects, as communication problems with clients, exacerbate the situation. Some failures occur so early in the project due to poor understanding of user requirements or because of poorly customizing an existing software application. In addition to that, lack of local standards for local software are factors that influence software project management indirectly.

There has been little or no research that specifically investigated the accuracy of software project estimation in Sudan. The contribution of this study to the existing body of knowledge is incorporating different viewpoints (governmental, educational, economical and administration) that gave a fuller picture about software projects failure reasons and support the strategic thinking of software companies in addressing the problems.

More research is required to study and evaluate the practice of project management in developing countries and to address salient issues such as the lack of local standards and accountability, in Sudan and elsewhere.

ACKNOWLEDGMENT

This project benefited from the support of the statistical unit at the Faculty of Mathematical Sciences. The first author benefited from the experience gained from their (a software company) to recognize and understand the problems of software estimation, as well as in the formulation of the research question. The authors wish to thank all participants for their willingness to share information about successes and failures in their work, which was key to producing this study and is greatly appreciated.

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