

PLANNING AGILE SOFTWARE PROJECTS WITH REDUCED GUESS
ESTIMATION

by

Buğra Kocatürk

B.S., Computer Engineering, Dokuz Eylül University, 2009

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Computer Engineering
Boğaziçi University

2011

ACKNOWLEDGEMENTS

This thesis would not have been possible without the help of several individuals who contributed and extended their valuable assistance in the preparation and completion of this study. I wish to express my deepest gratitude to all people who encouraged and supported me throughout the preparation of this thesis.

Especially I would like to thank my thesis supervisor Assoc. Prof. Tuna Tuğcu and Ph.D. Jean-Marc Desharnais for their guidance, invaluable academic feedback and patience during the study. They provided me the opportunity to work on my thesis with a great confidence. I also wish to express my sincere thanks to Prof. Cem Ersoy for kindly accepting to be committee member.

I would also like to thank Dr. Luigi Buglione for all his support and precious feedback. He shared his invaluable ideas and comments which helped me in completing my thesis.

I also want to present my sincere gratitude to Sezer Seçer, Melike Beşgen and Şöhret Hantal for their patience, invaluable support and advices.

Most importantly, I am indebted to my family for all their love and encouragement. They supported and helped me during my whole life.

The author of this thesis was supported by TÜBİTAK M.S. Fellowship BİDEB 2210 and Turkcell Akademi M.S. Fellowship.

ABSTRACT

PLANNING AGILE SOFTWARE PROJECTS WITH REDUCED GUESS ESTIMATION

Agile Project Management (APM) is the method of a series of commonly used project management approaches for better handling of uncertainty and unpredictability. In large portion of software projects, accurate planning of project lifetime with Agile is difficult. Since continuously change in requirements occurs as well their incompleteness at project initialization, project plans must be under control and continuously revised. The purpose of this thesis is to help tackling difficulties of managing Agile software projects by proposing an improved software planning technique. In Agile projects, planning is mainly based on just guess estimation of global effort. In the proposed approach, instead of just guess estimation, there is measurement of the size of the product. This measurement is implemented over user stories with COSMIC measurement and verification methods. Thus, needed efforts for the projects are calculated. The approach is applied on a film renting project in order to present its applicability. The results show that, by using the proposed approach, sizes of all pieces of the product can be obtained and by using the measurement results, project plans can be prepared with higher reliability and maintainability. Project plans may be more reliable, because they depend on solid measurement results and they may be more maintainable, because if any of the requirements changes, just that requirement needs to be measured again. Also it is shown that, documentation quality has an impact on the measurement results. As documentation quality changes, measurement results change by depending on the information in the documentation. It is also presented that, identification of the quality of the documentation helps to criticize the measurement.

ÖZET

ATIK METOT İLE GELİŞTİRİLEN YAZILIM PROJELERİNİN TAHMİNLER AZALTIYILARAK PLANLANMASI

Atik Proje Yönetimi (APY), günümüzde yaygın olarak kullanılan ve projelerdeki belirsizlikleri ve önceden tahmin edilemeyen problemleri yönetebilmeye olanak sağlayan metotlar bütünüdür. Fakat, projelerin büyük çoğunluğunda, tüm süreçlerin Atik metot ile doğru olarak planlanabilmesi zordur. Bu tip projelerde kullanıcı gereksinimleri sürekli değiştiği ve proje başlangıcında gereksinimlerin tamamı elde edilemediği için, proje planlarının sürekli kontrol altında tutulması gerekmektedir. Bu çalışmanın amacı, geliştirilmiş bir yazılım planlama tekniği sunularak, özellikle Atik yazılım projelerindeki problemlerin önüne geçilmesidir. Atik projelerde planlama, genelde sadece tahminlere dayanarak yapılmaktadır. Sunulan yöntemde, sadece tahminlere dayalı planlanlama yerine, yazılım projesinin büyüklüğü ölçümlenmektedir. Bu ölçümlendirme, kullanıcıdan alınan gereksinimler üzerinde, COSMIC ölçümlendirme ve COSMIC doğrulama metotları kullanılarak yapılmaktadır. Sonuç olarak, projenin gerçekleştirilmesi için gereken efor, geçmişe yönelik proje veritabanlarından da yararlanılarak hesaplanmaktadır. Geliştirilen metot, uygulanabilirliğini göstermek amacıyla, bir film kiralama projesi üzerinde uygulanmıştır. Elde edilen sonuçlar göstermektedir ki; bu metot kullanılarak, proje sonucunda ortaya çıkacak olan ürün en küçük parçasına kadar ölçümlenebilmekte ve proje planları daha güvenilir ve bakımı yapılabilir şekilde hazırlanabilmektedir. Ayrıca, kullanıcı gereksinimleri için hazırlanan döküman kalitesinin, ölçüm sonuçları üzerinde etkisi olduğu tespit edilmiş ve döküman kalitesinin tespit edilmesinin, ölçüm sonuçlarının değerlendirilmesinde büyük fayda sağladığı belirlenmiştir.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
ÖZET	v
LIST OF FIGURES	viii
LIST OF TABLES	ix
LIST OF ABBREVIATIONS	xvii
1. INTRODUCTION	1
1.1. Contribution of the Thesis	4
1.2. Organization of the Thesis	5
2. BACKGROUND	6
2.1. Agile Methodologies	6
2.1.1. Planning Poker	8
2.1.2. Incomplete Cyclic Design	9
2.2. COSMIC Methodologies	11
2.2.1. COSMIC Measurement Method	11
2.2.1.1. Identification of Data Movements	13
2.2.1.2. Application of Measurement Function	14
2.2.1.3. Aggregation of Measurement Results	14
2.2.2. COSMIC Verification Method for Rating Documentation Quality	15
2.3. ISBSG Repository	16
3. PROPOSED APPROACH	17
3.1. Identification of the User Requirements for Each User Story	18
3.2. Discussion on Formulation of the User Requirements to Find Functional Processes	19
3.3. Measurement of the Size of Each User Story with COSMIC Measurement Method	19
3.4. Determination of Quality of the Documentation with COSMIC Verifica- tion Method	20
3.5. Discussion on Effort per CFP Value	21

3.6.	Calculation of Overall Effort by Using Effort per CFP Value	22
3.7.	Preparation of the Project Plan According to the Calculated Effort . .	23
3.8.	Preparation of Other Iterations of Planning by Using New Information	24
4.	EXPERIMENTAL ANALYSIS AND RESULTS	25
4.1.	Project Description	25
4.2.	User Stories	26
4.3.	Functional Processes	27
4.4.	Application of COSMIC Measurement Method	28
4.4.1.	COSMIC Measurement Details of a Single Iteration of a Single User Story	28
4.4.2.	COSMIC Measurement Results	34
4.5.	Application of COSMIC Verification Method	38
4.6.	Calculation of Efforts	40
5.	CONCLUSION	44
	APPENDIX A: MEASUREMENT DETAILS OF ITERATIONS	47
A.1.	First Iteration	47
A.2.	Second Iteration	65
A.3.	Third Iteration	86
	REFERENCES	108

LIST OF FIGURES

Figure 2.1.	Relationships between data movement types and other concepts	14
Figure 3.1.	Steps of the proposed approach	17
Figure 3.2.	Relationships of the sub-concepts of user stories	19
Figure 4.1.	Sizes in CFPs per iteration	37
Figure 4.2.	Percentages of the quality of the documentations	40

LIST OF TABLES

Table 2.1.	COSMIC measurement method	12
Table 2.2.	Documentation quality rating scale	16
Table 4.1.	User stories for the first iteration of the film renting project	26
Table 4.2.	Functional processes of user stories of first iteration for film renting project	27
Table 4.3.	High level information of the first user story for first iteration	30
Table 4.4.	Measurement details of the functional process of user story	31
Table 4.5.	Measurement results of the first user story for first iteration	33
Table 4.6.	Measurement results of functional processes for all iterations	35
Table 4.7.	Measurement results of user stories for all iterations	36
Table 4.8.	Number of data movements for all iterations	37
Table 4.9.	Quality ratings of functional processes for all iterations	39
Table 4.10.	Percentages of quality ratings of functional processes for all iterations	39
Table 4.11.	Needed efforts for functional processes in person-hour	42
Table 4.12.	Needed efforts for user stories in person-hour	43

Table A.1. High level information of the second user story for first iteration . . . 47

Table A.2. Measurement details of the first functional process of second user story for first iteration 48

Table A.3. Measurement results of the second user story for first iteration . . . 49

Table A.4. High level information of the third user story for first iteration . . . 49

Table A.5. Measurement details of the first functional process of third user story for first iteration 50

Table A.6. Measurement results of the third user story for first iteration . . . 51

Table A.7. High level information of the fourth user story for first iteration . . . 51

Table A.8. Measurement details of the first functional process of fourth user story for first iteration 52

Table A.9. Measurement results of the fourth user story for first iteration . . . 53

Table A.10. High level information of the fifth user story for first iteration . . . 53

Table A.11. Measurement details of the first functional process of fifth user story for first iteration 54

Table A.12. Measurement results of the fifth user story for first iteration 55

Table A.13. High level information of the sixth user story for first iteration . . . 55

Table A.14. Measurement details of the first functional process of sixth user story for first iteration 56

Table A.15.	Measurement details of the second functional process of sixth user story for first iteration	57
Table A.16.	Measurement results of the sixth user story for first iteration . . .	58
Table A.17.	High level information of the seventh user story for first iteration .	58
Table A.18.	Measurement details of the first functional process of seventh user story for first iteration	59
Table A.19.	Measurement details of the second functional process of seventh user story for first iteration	60
Table A.20.	Measurement results of the seventh user story for first iteration . .	61
Table A.21.	High level information of the eighth user story for first iteration . .	61
Table A.22.	Measurement details of the first functional process of eighth user story for first iteration	62
Table A.23.	Measurement details of the second functional process of eighth user story for first iteration	63
Table A.24.	Measurement results of the eighth user story for first iteration . . .	64
Table A.25.	High level information of the first user story for second iteration .	65
Table A.26.	Measurement details of the first functional process of first user story for second iteration	66
Table A.27.	Measurement details of the second functional process of first user story for second iteration	67

Table A.28.	Measurement results of the first user story for second iteration . . .	68
Table A.29.	High level information of the second user story for second iteration	68
Table A.30.	Measurement details of the first functional process of second user story for second iteration	69
Table A.31.	Measurement results of the second user story for second iteration .	70
Table A.32.	High level information of the third user story for second iteration .	70
Table A.33.	Measurement details of the first functional process of third user story for second iteration	71
Table A.34.	Measurement results of the third user story for second iteration . .	72
Table A.35.	High level information of the fourth user story for second iteration	72
Table A.36.	Measurement details of the first functional process of fourth user story for second iteration	73
Table A.37.	Measurement results of the fourth user story for second iteration .	74
Table A.38.	High level information of the fifth user story for second iteration .	74
Table A.39.	Measurement details of the first functional process of fifth user story for second iteration	75
Table A.40.	Measurement results of the fifth user story for second iteration . .	76
Table A.41.	High level information of the sixth user story for second iteration .	76

Table A.42.	Measurement details of the first functional process of sixth user story for second iteration	77
Table A.43.	Measurement details of the second functional process of sixth user story for second iteration	78
Table A.44.	Measurement results of the sixth user story for second iteration . . .	79
Table A.45.	High level information of the seventh user story for second iteration	79
Table A.46.	Measurement details of the first functional process of seventh user story for second iteration	80
Table A.47.	Measurement details of the second functional process of seventh user story for second iteration	81
Table A.48.	Measurement results of the seventh user story for second iteration	82
Table A.49.	High level information of the eighth user story for second iteration	82
Table A.50.	Measurement details of the first functional process of eighth user story for second iteration	83
Table A.51.	Measurement details of the second functional process of eighth user story for second iteration	84
Table A.52.	Measurement results of the eighth user story for second iteration . . .	85
Table A.53.	High level information of the first user story for third iteration . . .	86
Table A.54.	Measurement details of the first functional process of first user story for third iteration	87

Table A.55.	Measurement details of the second functional process of first user story for third iteration	88
Table A.56.	Measurement results of the first user story for third iteration . . .	89
Table A.57.	High level information of the second user story for third iteration .	90
Table A.58.	Measurement details of the first functional process of second user story for third iteration	91
Table A.59.	Measurement details of the second functional process of second user story for third iteration	92
Table A.60.	Measurement results of the second user story of third iteration . .	93
Table A.61.	High level information of the third user story for third iteration . .	93
Table A.62.	Measurement details of the first functional process of third user story for third iteration	94
Table A.63.	Measurement results of the third user story for third iteration . . .	94
Table A.64.	High level information of the fourth user story for third iteration .	95
Table A.65.	Measurement details of the first functional process of fourth user story for third iteration	96
Table A.66.	Measurement results of the fourth user story for third iteration . .	97
Table A.67.	High level information of the fifth user story for third iteration . .	97

Table A.68.	Measurement details of the first functional process of fifth user story for third iteration	98
Table A.69.	Measurement results of the fifth user story for third iteration . . .	98
Table A.70.	High level information of the sixth user story of third iteration . .	99
Table A.71.	Measurement details of the first functional process of sixth user story for third iteration	99
Table A.72.	Measurement details of the second functional process of sixth user story for third iteration	100
Table A.73.	Measurement results of the sixth user story for third iteration . . .	101
Table A.74.	High level information of the seventh user story for third iteration	101
Table A.75.	Measurement details of the first functional process of seventh user story for third iteration	102
Table A.76.	Measurement details of the second functional process of seventh user story for third iteration	103
Table A.77.	Measurement results of the seventh user story for third iteration .	104
Table A.78.	High level information of the eighth user story for third iteration .	104
Table A.79.	Measurement details of the first functional process of eighth user story for third iteration	105
Table A.80.	Measurement details of the second functional process of eighth user story for third iteration	106

Table A.81. Measurement results of the eighth user story for third iteration . . .	107
--	-----

LIST OF ABBREVIATIONS

APM	Agile Project Management
ASD	Agile Software Development
CFP	COSMIC Function Point
DM	Data Movement
FSM	Functional Size Measurement
FUR	Functional User Requirement
ISBSG	International Software Benchmarking Standards Group
LOC	Lines of Code
NFR	Non-Functional User Requirement
PDR	Project Delivery Rate

1. INTRODUCTION

In order to make more reliable plans for software projects under continuously changing requirements, Agile Project Management (APM) [1, 2] is one of the options used to plan the development of the projects. While Agile Software Development (ASD) [3] methodologies are for the development and enhancement, APM methodologies are for the planning. APM is particularly useful when requirements [4] are continuously changing during the project lifetime and/or are strongly incomplete at the project initialization phase. APM includes a series of commonly used project management approaches that should help handling uncertainty [5] and unpredictability. It helps software project managers and employees to adapt to unsteady circumstances, instead of trying to impose formal controls, as in traditional linear development methods [1]. It is widely used in different software projects from different application domains.

Ideally a project should be completed within budget, schedule, and at the required quality level. For instance, in a large portion of software projects, accurate planning (and estimation) of whole project lifetime with Agile is difficult, even when using APM. Since a continuous change in (product) requirements occurs as well their incompleteness at the project initialization phase, project plans must be under control, and they must be continuously revised according to user needs and project resources. Under control means knowing, at least, if the project is on budget and schedule at any time during the project.

In Agile software projects, project plans are not necessarily reliable, because many factors should be considered while planning. It is known that Agile software processes has some limitations [6], but it is needed to overcome those problems. For instance, Expert Judgment (based on guess estimates) as defined by many authors including Boehm [7], does not consider separately the change in the nature and overall size of a software product, the resources that can be used during the projects, and the estimation of the total effort, but globally. From such perspective, most of the time, Agile software projects are only guess estimated [8, 9]. Boehm's parametric approach (COCOMO)

[7, 10] takes Lines of Code¹ (LOC), a series of productivity factors (resources) and Project Delivery Rate (PDR, hours per KLOC)² into account. To keep project plans under control, it is then necessary to continuously monitor the size of the product and take the productivity of the resources into account.

The purpose of this work is to propose an improved software planning technique to be used mainly in Agile software projects, by using separate measures for the product (size), the process (time, quality) and the resources (productivity factors). This is the base for a parametric approach as defined by different authors [11, 12]. A decade after Barry Boehm wrote *Software Engineering Economics* [7], Norman Fenton described, in terms of measurement, the different measures used in a parametric approach [13]. These classifications of Software Measures are defined in the following way by Fenton:

- Products are any artifacts, deliverables or documents that result from a process activity. (e.g., LOC and function point)
- Processes are collections of software-related activities. (e.g., to measure the activity in terms of five hours per function point)
- Resources are entities (also called productivity factors) required by a process activity (e.g., experience of the developers, language, etc., expressed in terms of percentage that could affect the process, hours per function point).

Size³ of the software product is first determined by using user stories, as well as the quality of the documentation of user stories at different steps. In this thesis, Functional Size Measurement (FSM) method is used instead of LOC to overcome the problem of measuring different languages with different measurement results. It is not possible to compare directly a KLOC in Assembler with a KLOC in Java. The measurement [15, 16] method associated with FSM that is used in this thesis is COSMIC [17, 18] and the sizes are represented in terms of COSMIC Function Points (CFP) [19, 20].

¹Note that LOC does not measure the size of software, but only its length.

²Hours per KLOC is the inverse of PDR and often called unit effort or unit cost.

³For any entity, several attributes can be also measured (and therefore sized) according to a different unit of measure. Of course the same occurs also with whatever function point unit, no matter which FSM method adopted [14].

To obtain the effort and the productivity factors, the project historical database, the International Software Benchmarking Standards Group (ISBSG) is used [21, 22].

A parametric approach for planning Agile [23] software projects is proposed in this thesis. In this approach, it is shown that user stories can be measured [24, 25] by using the COSMIC measurement method that permits going to the detail of each story as the project evolves. Also, the quality of the documentation of requirements is studied. Our hypothesis is that the quality of the documentation has an impact on the measurement results [26]. This helps to identify indirectly the acceptability of the measurement results.

This approach has the following steps to reduce guess estimation [27, 28] in software project planning and produces a more reliable and verifiable way with a few measurement iterations:

- (i) Identification of the user requirement for each user story.
- (ii) Discussion on formulation of the user requirements to find functional processes.
- (iii) Measurement of the size (CFP) of each user story with COSMIC measurement method.
- (iv) Determination of quality of the documentation of each user story with COSMIC verification method.
- (v) Discussion on effort per CFP value.
- (vi) Calculation of overall effort by using effort per CFP value.
- (vii) Preparation of project plan according to the calculated effort.
- (viii) Preparation of other iterations of planning by using new information (optional).

After all iterations of measurement are completed, final overall effort of the projects is obtained. Thus, instead of just guess estimation, we make the hypothesis that the determination of the effort can be more reliable and verifiable by using different steps to implement the proposed specific parametric approach.

1.1. Contribution of the Thesis

Planning Agile software projects [29] requires a capability of handling uncertainty and unpredictability in the requirements. Since user requirements cannot be taken completely at the project initialization, and they continuously change, it is not easy to prepare accurate and reliable plans for Agile software projects. The reason behind this fact is, the needed effort for implementation of the project cannot be determined accurately.

Since existing approaches for planning Agile software projects are based on guess estimations of the needed efforts, plans are not prepared with a confidence. Guess estimations are based on expert judgements and they do not provide a reliable way of effort determination. Thus, prepared project plans, by using these effort values, do not have satisfying reliability.

In this thesis, a new approach is presented, which measures the functional size of the software, to be developed, in order to determine the needed effort. Thus, instead of just guess estimation, measurement results are used for preparing project plans. Additionally, the quality of the documentation, prepared for user requirements, is measured with this approach. This provides the ability to analyze the functional size measurement results and helps to increase the available information in documentations.

The contributions of this thesis can be listed as follows:

- The approach helps to reduce guess estimation in planning Agile software projects.
- The approach helps to increase the reliability and accuracy of the software project plans.
- The approach helps to increase the quality of the documentaion for defining user requirements.
- The approach helps project managers to easily maintain prepared software project plans with the help of measurement results.

1.2. Organization of the Thesis

Chapter 2 presents background information on Agile methodologies and COSMIC methods. Chapter 3 describes the proposed approach and presents its details. Chapter 4 includes the analysis of the approach and finally Chapter 5 concludes the thesis with evaluation of the work and presents future works.

2. BACKGROUND

In order to represent the idea behind the thesis clearly, it is important to explain some beneficial concepts, which are referred in the proposed approached.

2.1. Agile Methodologies

Agile methodologies are commonly used for effectively responding quick changes in the requirements [30]. The term Agile, denotes “the quality of being agile, readiness for motion, nimbleness, activity, and dexterity in motion” [3]. When compared with the traditional approaches, Agile methods [31, 32] are more adaptive and less predictive as well as being more people-oriented and less process-oriented [33]. These properties provide faster responses to sudden changes.

Agile methodologies gained progress with the development of Agile Manifesto [34], which proposes a series of values and principles typically to manage a project. The four original values⁴ are:

- Individuals and interactions over processes and tools,
- Working software over comprehensive documentation,
- Customer collaboration over contract negotiation,
- Responding to change over following a plan.

The left hand side values are considered to be more relevant than those on the right hand side, assigning more power to people than to the project since producing software as quickly as possible has higher priority.

With the reference of mentioned values, 12 principles are set behind the Agile Manifesto [34]:

⁴A debate is going on during last years about the revision of the Agile Manifesto [35-38].

- Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
- Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
- Business people and developers must work together daily throughout the project.
- Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
- The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
- Working software is the primary measure of progress.
- Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
- Continuous attention to technical excellence and good design enhances agility.
- Simplicity - the art of maximizing the amount of work not done - is essential.
- The best architectures, requirements, and designs emerge from self-organizing teams.
- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

In projects that adopt these principles, main concern is about the missing well-defined project plan. Since a project plan is the skeleton on which the project lives, it provides and distributes the information on time scheduling, effort planning, resource and budget planning, and drives to the achievement of aimed business goals.

Project plans in Agile contexts are prepared according to the requirements taken from the users, but also involves the customers more actively during the whole project lifetime. Such requirements are typically expressed by short sentences (user story) expressing the (functional) to-dos from the user's point of view. In most known Agile approaches, a user story represents a high-level requirement that typically expresses the functional size. It is a brief statement of intent that describes something the system

needs to do for the user and describes a feature of the software [39, 40]. Each user story is formulated in one or two sentences in the language of the customer, and typically written on a small index card. Instead of conveying all details about the feature, they maintain just brief descriptions. The details are then fleshed out in the conversations, conveyed and documented [41].

After user stories are taken from the user, in general approaches, the following step is about estimating the effort needed for implementing all of them. However, this estimation process needs a rigorous approach. In order to handle this difficulty, different approaches are proposed. Planning Poker [42] and Miranda's Incomplete Cyclic Design [8] are two of them and they are described in this thesis.

2.1.1. Planning Poker

Planning Poker is used to estimate the amount of effort needed to implement the user story by combining expert opinion, analogy and disaggregation [42]. For Planning Poker, there must be a group of people (experts) who are included in the project team. These participants then begin to analyze the user stories one by one and rate them according to their complexities. At the end of the discussions, the group comes to a consensus and the decision is given about the user story.

In Planning Poker approach, every estimator has a deck of numbered cards. The numbers on the cards represent the estimates for the amount of works. The selected person (moderator) reads the description of the user story and questions of estimators are accepted and answered. After the discussion is completed, each estimator selects a numbered card from his/her own deck. This selection represents the estimation of that estimator for the amount of work needed for the user story. These selected cards are kept private until each estimator selects a card. When all estimators select cards, every estimator shows his/her estimation number.

In Planning Poker approach, it is very common that the estimates differ from one estimator to another. However, it is not considered as bad news because, in this

case, the high and low estimators are able to explain their own ideas about the user stories, and they need to justify their explanations with solid ideas so that they are able to convince other estimators. So, the discussions begin once more. After discussing again, each estimator selects one more card. The same rules apply as in the previous round. This process continues until all or many of the estimators select same cards. It is important for the moderator to decide when to stop the estimation process. For instance if five of six estimators pick the same card and the other one selects different card, the moderator asks the different estimator whether he/she agrees with the mostly preferred estimation. If he/she agrees, then the iteration stops. Otherwise, it continues.

There are both positive and negative sides of Planning Poker approach. From the positive side, many experts come together and each of them shares different ideas with different perspectives, because there are different estimators with different knowledge and skills. Additionally, different works show that averaging individual estimates leads to better results [43] by performing group discussions [44].

From the negative side, Planning Poker approach is still not very reliable since it includes just guess estimation. It still does not include any parametric approach which brings evidences and more accuracy into estimations.

2.1.2. Incomplete Cyclic Design

A modified version of Paired Comparison Method [45-47] is developed by Eduardo Miranda. It includes comparisons [48] of the requirements. Miranda's methodology supports expert judgment, which is one of the sizing methods used in industry. In Miranda's method, total number of comparisons in Paired Comparison Method is reduced nearly by half with the help of Incomplete Cyclic Designs to select suitable pairs of entities to be compared [8].

In traditional user story comparisons, the process continues with comparing each user story with other ones and estimating its size according to each previously estimated user story. For instance, a group of people come together and decide the size of

the first user story. Then, it is time for the size estimation of the second user story. The discussion for the second user story includes the previous estimation result. So, comparing the first one provides a second user story estimation, and a sentence like “This story is bigger than the first one so it needs higher value” is presented. This operation replicates for the third user story, however the situation is a bit different now. The third user story estimation is made by comparing it with all previous estimations, so it is compared with the two previous ones.

Traditional approaches are not good enough to produce reliable estimates. The very first reason is that, as number of user story increases, the number of comparisons also increases. This means that too much effort is needed to make the estimations for all user stories. It is also hard to decide the number of comparisons at the beginning of the estimation process.

To solve above mentioned problems, Miranda proposes the use of Incomplete Cyclic Designs to identify which user story to compare with which one to reach a desired accuracy and the use of the Paired Comparison Method to deal with judgment inconsistencies.

Paired Comparison Method mainly estimates the size of user stories by comparing their relative largeness rather than to provide absolute size values. Then, one of the estimated user stories is assigned a random number of story points. Using this user story as reference, sizes of all other user stories are determined in terms of story points. Since all user stories are compared with each other, this process is called as “Full Factorial Pairwise Comparison” [8].

In order to improve the described paired comparison method, Incomplete Cyclic Design is used in Miranda’s approach. By using Incomplete Cyclic Design, numbers of comparisons, needed for the estimation of user stories, are decreased. Incomplete Cyclic Design helps to improve the estimation process with a lower effort, because each user story does not need to be compared with other user stories. Just a few of them are compared with other user stories, and the remaining ones can be estimated by using

these comparison results. So, this method can be considered as acceptable since it decreases the needed effort to make comparisons.

There is still a problem about this approach. As in the case of Planning Poker, Miranda's approach is also just guess estimation. It is still not possible, for example, to determine if the global effort increase is due to the increase of the size of the product or the increase of the unit cost or to keep historical data that can be compared project to project. It relies on the particular knowledge of the individual who is doing the planning.

2.2. COSMIC Methodologies

COSMIC method is mainly used to measure the functional size of the functional processes, but recently the use of COSMIC measurement method is also considered to evaluate the quality of the documentation [26].

2.2.1. COSMIC Measurement Method

COSMIC is a measurement method [49, 50] that was accepted by ISO/IEC JTC1 SC7 in December 2002, as an International Standard (ISO/IEC 19761 "Software Engineering - COSMIC-FFP - A functional size measurement method") [17]. It involves applying a set of models, principles, rules, and processes to the Functional User Requirements (FUR) of a given piece of software to produce a numerical value of a quantity which represents the functional size of the piece of software according to the COSMIC method [17, 18]. FUR describes what the software must do for the functional users, which are senders of data to the system and intended recipients of data from the system, and it completely excludes any requirements that states how the software performs.

As defined in the COSMIC measurement manual, purpose of the COSMIC method is to provide a standardized method of measuring a functional size of software from the functional domains commonly referred to as business application (or MIS) software

and real-time software. Measured functional sizes are independent of all technology decisions and implementation details of the software. For this reason, COSMIC method can be applied as soon as user requirements are determined. There is no need to wait for the implementation. The general measurement process for COSMIC includes three phases, which can also be seen as summarized in Table 2.1:

- The Measurement Strategy Phase, in which the Software Context Model is applied to the software to be measured, purpose and the scope of the measurement are determined in addition to the functional users and level of granularity of the measurement.
- The Mapping Phase, in which the Generic Software Model is applied to the software to be measured, functional processes and data groups are identified, and FURs are obtained.
- The Measurement Phase, in which actual size measurements are made, data movements are identified and measurement function is applied in addition to the aggregation of measurement results.

Table 2.1. COSMIC measurement method

Phase	Steps
Measurement Strategy Phase	Definition of purpose of the measurement
	Definition of scope of the measurement
	Identification of functional users
	Identification of level of granularity
Mapping Phase	Application of Generic Software Model
	Identification of functional processes
	Identification of objects of interest and data groups
Measurement Phase	Identification of data attributes
	Identification of data movements
	Application of measurement function
	Aggregation of measurement results

At the end of the Measurement Phase, functional size of the software is obtained in terms of CFP. So, it is important to analyze the details of this phase. As described above, this phase consists of three main steps which can be listed as:

- Identification of data movements.
- Application of the measurement function.
- Aggregation of the measurement results.

2.2.1.1. Identification of Data Movements. A data movement is a base functional component, which moves a single data group type which is a distinct, non-empty, non-ordered, and non-redundant set of data attributes where each included data attribute describes an aspect of the same object of interest [18]. There are four sub-types of data movement types:

- Entry data movement, which moves a data group from a functional user to the functional process where it is required.
- Read data movement, which moves a data group from a persistent storage to the functional process that requires it.
- Write data movement, which moves a data group from a functional process to a persistent storage.
- Exit data movement, which moves a data group from a functional process to the functional user that requires it.

The relationships of data movement types are shown in Figure 2.1 [18].

In order to walk through the measurement, each data movement must be identified after functional processes are determined. As shown in Figure 2.1, there is a strong relationship between these data movements and data groups since data movements move identified data group types towards related concept.

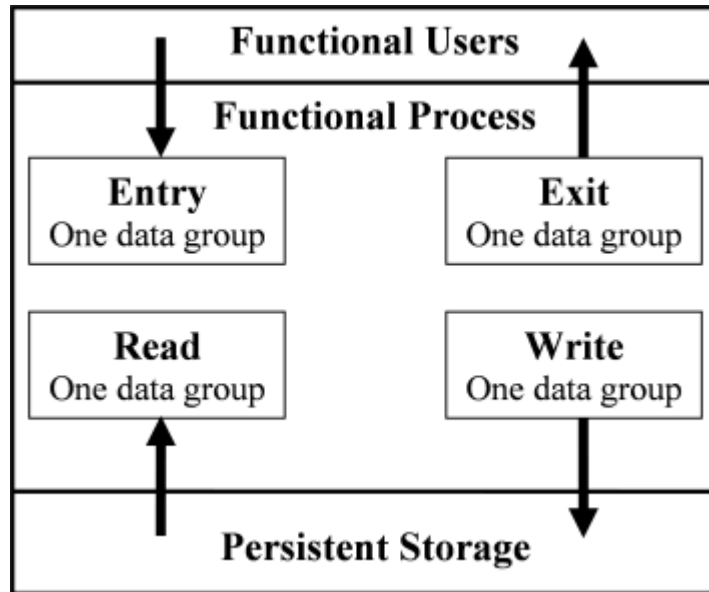


Figure 2.1. Relationships between data movement types and other concepts

2.2.1.2. Application of Measurement Function. In this step, COSMIC measurement function is applied to each data movement identified in functional processes where COSMIC measurement function represents a mathematical function which assigns a value to its data movement based on the COSMIC measurement standard [17]. According to COSMIC measurement standard, size of one data movement is identified as one CFP. So, each identified data movement is counted as one CFP after measurement function is applied.

2.2.1.3. Aggregation of Measurement Results. After measurement function is applied to each data movement, the results must be aggregated into one functional size value. The aggregation of the results consists of adding up all identified CFPs of each functional process. This aggregation function is shown in Equation (2.1).

$$\begin{aligned}
 size(FP_i) = & \sum size(Entry_i) + \sum size(Read_i) \\
 & + \sum size(Write_i) + \sum size(Exit_i)
 \end{aligned}
 \tag{2.1}$$

where, i is the functional process number. The result of this equation shows the size of the i the functional process in terms of CFPs.

For example, if a functional process x has two Entry data movements, three Read data movements, three Write data movements, and one Exit data movement, the calculation is as following:

$$\begin{aligned} size(FP_x) &= 2 + 3 + 3 + 1 \\ &= 9 CFPs \end{aligned}$$

Above mentioned calculation gives the functional size of the measured functional process in terms of CFPs, and it can be applied to all identified functional processes in order to find the overall functional size of given software piece.

2.2.2. COSMIC Verification Method for Rating Documentation Quality

COSMIC method is used for measuring the functional size of the functional processes. However, it is also possible to identify the quality of the documentation of the functional processes by using COSMIC verification method [26]. This quality rating operation is a good support to the measurement, and it provides indirectly the capability of analyzing the quality of the measurement result (CFP).

After each functional process is measured in terms of CFP, the documentation for each functional process is checked based on a number of criteria. Thus, the reliability and acceptability of the measurement is identified. Since there is a rating for each functional process, documentation of each functional process must be analyzed separately. According to the available documentation of each functional process, quality of the measurement results is analyzed, and this provides the opportunity to determine whether the measurement is reliable or not. The rating scale for the documentation quality is from (a) to (e), and their descriptions according to COSMIC guide [26] are shown in Table 2.2.

Table 2.2. Documentation quality rating scale

Rating	Description
a	The functional process is completely documented together with its data movements by type.
b	The functional process is documented but the description of the data moved is unclear. The input, output, stores and retrievals of each functional process are also described but not clearly enough to identify the number of data movements.
c	The functional process is identified only but their data movements are not.
d	The number of the functional process is given but they are not specified.
e	The functional process is not mentioned in the artifacts but is implicit.

2.3. ISBSG Repository

ISBSG [21] repository is a collection of more than 5000 projects, each one having the following types of information in accordance to different type of measurements described by Fenton:

- Functional size (it can be the functional size from any of the FSMs)
- Effort in hours (normally this information is related to the development or enhancement part of the life cycle of a project)
- Different characteristics for each project (more than a hundred characteristics like the domain, the language, the experience of the IT people, etc.)

This valuable information is able to be used as a project historical database (more details on how to use it are described in Section 3.5). The projects in this repository act as a reference point for the estimations and ISBSG repository plays an important role as a reliable and valuable information source for many researchers.

3. PROPOSED APPROACH

This thesis presents an approach, which suggests measuring the functional size of user stories by using the COSMIC measurement method in order to determine the effort needed for implementation and verifying the measurement results by identifying the quality of the documentation with COSMIC verification method [26]. This approach brings the advantages of not only guess estimating the effort values, but having a systematic way of measurement of the product and then determining the needed efforts. Additionally, it is possible with this approach to identify the quality of the applied measurement. Proposed approach helps organizations to have a trustable and repeatable consistent way for project planning. Figure 3.1 shows the steps needed to apply the proposed approach.

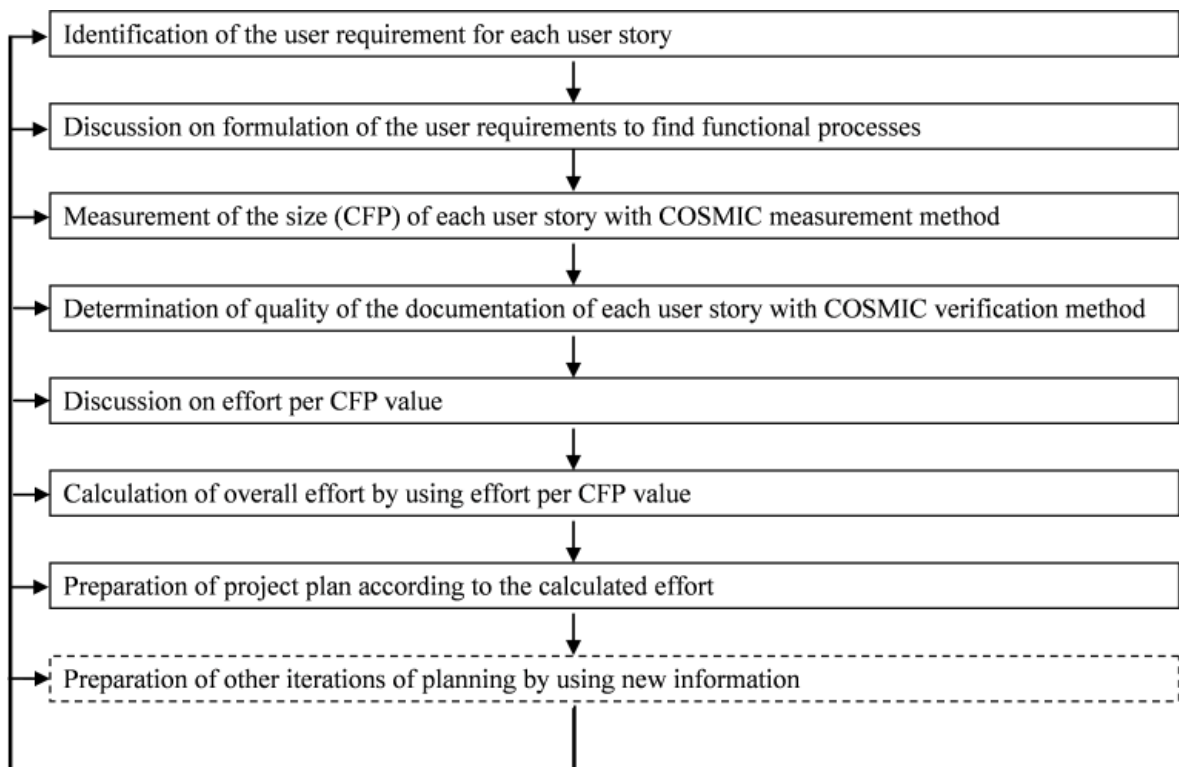


Figure 3.1. Steps of the proposed approach

In Figure 3.1, the steps with continuous lined boxes are mandatory whereas the step with dashed lined box is optional. From the figure, it can be seen that the approach consists of eight steps, one of which is optional.

3.1. Identification of the User Requirements for Each User Story

In the very first step of the approach, user requirements need to be determined and taken in the form of user stories. As already mentioned previously, a user story is a brief statement of intent that describes something the system needs to do for the user [39]. So, this step provides all information about the requirements of the system and has an important impact on the overall calculations.

In this step, requirements of the users must be understood clearly and they must be presented in a standardized way. This standardization may be provided with a single user story template like the one used by Leffingwell and Behrens [39]. For example, using following template may be helpful to present all user stories in the same way:

As a <role>, I want to be able to <activity> so that <business value>.

where, <role>describes the performer of the activity or the one who is receiving value from the activity, <activity>describes the action to be performed by the system and <business value>describes the value to the business of the activity if any (optional).

By using this template, an example user story looks like as follow:

As a customer, I want to be able to rent a film on-site so that I can watch it at my home.

In this example, “customer” is the role, “rent films on-site” is the activity, and “I can watch them at my home” is the business value.

The relationships between the concepts of the template are shown in Figure 3.2. As also seen in the figure, the business value is optional.

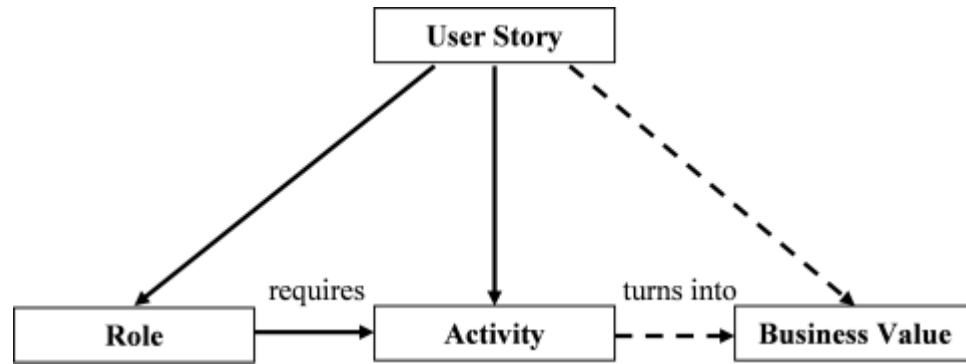


Figure 3.2. Relationships of the sub-concepts of user stories

3.2. Discussion on Formulation of the User Requirements to Find Functional Processes

After identifying the user stories from the users, the developers formulate them in terms of functional processes. One user story may include more than one functional process and all those functional processes must be found out. However, it is not observed that more than one user story is a part of only one functional process. Identification of the functional processes is at the mapping phase of COSMIC measurement method (Table 2.1). In order to extract the functional processes from user stories, separate events of functional users need to be identified. Those events generally trigger one functional process. Identification of all functional processes is important since each functional process needs to be measured in later steps. If any of the functional processes cannot be caught, measurement results may change according to the scope of the functional process.

3.3. Measurement of the Size of Each User Story with COSMIC Measurement Method

Third step of the approach is to apply COSMIC measurement method. In order to be able to find the size of a user story, all of its functional processes must be measured in terms of CFP by using COSMIC measurement method. Since the size of a user story consists of the sum of the size of each functional process that builds up that user story, there may be more than one measurement needed for some user stories.

After getting user requirements in the first step and identifying the functional processes in the second step, further information may be needed before applying the measurement function. The measurer can ask specific questions about missing information. In case of absence of the required information, assumptions are prepared and the measurement continues with regards to those assumptions.

Details of measuring the size of a functional process in terms of CFP can be found in the COSMIC measurement manual [18]. In summary, it consists of three steps, which are “identification of data movements”, “application of measurement function”, and “aggregation of measurement results”. Once data movements are identified as Entry, Read, Write, and Exit, numbers of data movements are added up to obtain the size of the functional process.

3.4. Determination of Quality of the Documentation with COSMIC Verification Method

COSMIC guideline for assuring the accuracy of measurements [26] recommends obtaining the rating for a set of software documentation (the software artifacts rating), in a less subjective way than just making a single judgment based on a given criteria like “Good”, “OK” or “Poor”.

The recommendation of the approach is to rate each identified functional process in the set of software artifacts on the scale (a) to (e) as it is shown in Table 2.2. This evaluation of the quality of the documentation is based on facts some of which can be listed as:

- The presence or absence of a data model.
- The presence or absence of information to identify the data movements (entry, read, write, exit).
- The presence or absence of a documentation to identify each functional process.

According to the provided information, each functional process needs to be rated

for its documentation quality. For this reason, after the measurement step, each functional process is assigned a rating for documentation quality. This means that, each functional process has a size value in terms of CFP and a quality rating value from (a) to (e). This helps to decide whether the measurement results are reliable or not and has an important role in whole measurement process.

3.5. Discussion on Effort per CFP Value

After the CFP for each user story is determined, the next step is to calculate the effort to implement each of them. In order to do this, effort per CFP value needs to be determined. There are different ways for determination of this value. Group of experienced people may find an agreement on such value by discussions or derive it from a repository of previously implemented projects, selecting their more feasible effort per CFP range of values after applying some filters by the needed project characteristics (e.g. development type, programming language(s), application domain, etc.).

A valuable reference point for benchmarking and/or when the organizational project historical database is not present or contains few reference data, is the ISBSG [21] repository. In order to be effective as much as possible in the estimation process, it must be remembered that currently ISBSG data does not split the effort by requirement type (functional vs non-functional), but only proposes a split by high level phases as discussed by Dèry and Abran [22]. Therefore, a suggestion is to derive - at least with a high-level view - the proportion between the effort derived from FUR and Non-Functional User Requirements (NFR) for each project type, in order to properly manage PDR variability and ranges in the estimation process [51].

A typical calculation of the effort per CFP value for a project by using ISBSG historical database consists of the following steps:

- (i) Establishment of the criteria to choose typical projects from the historical database (e.g. MIS domain, java language, etc.).
- (ii) Applying a filter on the historical database according to specified criteria.

- (iii) Calculation of the lower, average, and higher effort per CFP which gives unit effort.
- (iv) Calculation of the R-square to determine the reliability of the results (more than 70% R-square is good while less than 50% R-square is not very reliable).
- (v) Decision on the effort per CFP to apply which may be a single or a range of unit effort.

By using project historical database, determination of the effort per CFP value depends on some facts, and it is possible to be aware of the reliability of the judgment. So, a reference project historical database is able to be used for the determination of effort per CFP value, and this step is also important since the determined value can be useful for the calculation of overall effort needed.

The decided effort per CFP value can be applied to whole project. However, if there is an exceptional user story (or functional process), which is very hard to implement and may require higher effort than the decided one, it is also possible to identify a new effort per CFP value for only that user story (or functional process). This is the only subjective part of the proposed approach; however, it still depends on the measurement results, and it is optional. Also, in the mentioned case, there is still not guess estimation about the size since size of the user story (or functional process) is already measured.

3.6. Calculation of Overall Effort by Using Effort per CFP Value

After effort per CFP is determined, it is necessary to calculate the overall effort in terms of hours for each functional process, then for each user story and finally for whole project. This operation includes multiplication and addition of previously calculated values.

In order to calculate the effort of a functional process, effort per CFP value is multiplied by the number of CFP value for the functional process. Equation (3.1) shows

the calculation of effort for a functional process.

$$E(US_iFP_j) = CFP_j * E_j \quad (3.1)$$

where, i is the identification number of the story to which the functional process belongs to and j is the identification number of the functional process.

In order to calculate the effort of a user story, all effort values of its functional processes must be added up. Equation (3.2) shows the calculation of effort for a user story.

$$E(US_i) = \sum_{j=1}^k E(US_iFP_j) \quad (3.2)$$

where, i is the identification number of the user story, j is the identification number of the functional process, and k is the number of functional processes in user story i .

In order to calculate the overall effort of the project, all effort values of its user stories must be added up. Equation (3.3) shows the calculation of overall effort for a project.

$$E(Project_m) = \sum_{i=1}^n E(US_i) \quad (3.3)$$

where, m is the identification number of the project, i is the identification number of the user story, and n is the number of user stories in project m .

3.7. Preparation of the Project Plan According to the Calculated Effort

Preparation of the project plan is under the responsibility of the project manager. Since the measurement results yield the overall effort in terms of hours; he/she can make the schedule, resource or budget plans according to provided measurement results. Thus, a more measurement based project plan returns a better reliability and accuracy,

in addition to providing benefits for all stakeholders.

3.8. Preparation of Other Iterations of Planning by Using New Information

As the project and the measurement evolve, more information may be coming in. This information may be additional information to the existing user stories, but it is also possible that previous requirements may change. So, the measurement may need a revision in order to reflect the new information to the measurement results. In this case, new iterations of the approach occurs in order to apply the measurement rules to new or changed user stories. These new iterations have more accurate results, since there are clearer information about the previous assumptions. According to the information available, size of the previously measured user stories may change or remain same, but in all cases the results reflect most up-to-date and reliable measurements. Note that this step is optional since there may be no new information or the information is not collected.

4. EXPERIMENTAL ANALYSIS AND RESULTS

The approach proposed in this thesis is performed on a “film renting project” in order to show its applicability and to analyze the results.

4.1. Project Description

In the most basic terms, there is a film renting shop with employees, and there are customers who are able to rent films from the shop.

User requirements for the project are taken in terms of user stories. These stories represent the needs of the employees and the customers. The approach is applied to the film renting project according to the requirements of mentioned stakeholders, but all requirements could not be taken at the beginning of the project. For this reason, three iterations are performed with the approach.

In the first iteration, there is missing information about the requirements so that some questions arise. For these questions, assumptions are provided within the first iteration. After missing information is obtained, second iteration is performed; then more information is coming. So, the third and the final iteration⁵ is performed with, ideally, the full information. However, during these iterations, new user requirements arise which is the case in many Agile projects. So, for each iteration, there are additional requirements from the user in addition to the provided missing information.

After the approach is applied for each iteration, final results are obtained. These results show the applicability of the approach and produces easy-to-use valuable information for project managers.

⁵It is decided to have only three iterations for the purpose of the demonstration in this thesis.

4.2. User Stories

There are eight user stories in the film renting project. Table 4.1 shows the user stories for the first iteration of film renting project.

Table 4.1. User stories for the first iteration of the film renting project

Identifier	User Story
IT1-US1	As a customer I want to be able to rent a film so that I can watch it at my home.
IT1-US2	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal so that I can find a film as I wish.
IT1-US3	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.
IT1-US4	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.
IT1-US5	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.
IT1-US6	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.
IT1-US7	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.
IT1-US8	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.

The “Identifier” column of Table 4.1 shows the unique aliases of the stories. “IT” is the representation of “iteration” whereas “US” is the representation of “user story”. For example, “IT1-US5” is used for the fifth user story of first iteration for film renting project.

User stories reflect the needs of the user. However, according to the provided information, some of the presented user stories change in second or third iterations to adapt to new requirements or to reflect the new information. User stories of second and third iterations are not shown here, since they can be extracted from Appendix A.

4.3. Functional Processes

In order to apply the COSMIC measurement and COSMIC verification methods, it is necessary to identify all functional processes of each user story. Since one user story may include more than one functional process, number of functional processes may not match with the number of user stories. This is also the same case for the film renting project. There are eight user stories in the film renting project, however, there are 11 functional processes of the user stories for first iteration. Table 4.2 shows the functional processes of user stories of first iteration. Functional processes of second and third iterations are not shown here, since they can be extracted from Appendix A.

Table 4.2. Functional processes of user stories of first iteration for film renting project

Identifier	Functional Process
IT1-US1-FP1	Customers can rent films on-site.
IT1-US2-FP1	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
IT1-US3-FP1	Customers can criticize the films by using on-site terminal.
IT1-US4-FP1	Customers can view criticism of films via on-site terminal.
IT1-US5-FP1	Customers can raise a request for a nonexistent film on-site.
IT1-US6-FP1	Employees can add a film into the system.
IT1-US6-FP2	Employees can delete a film from the system.
IT1-US7-FP1	Employees can add a customer into the system.
IT1-US7-FP2	Employees can delete a customer from the system.
IT1-US8-FP1	Employees can add a promotion into the system.
IT1-US8-FP2	Employees can delete a promotion from the system.

The “Identifier” column of Table 4.2 shows the unique aliases of the functional processes. “IT” is the representation of “iteration”, “US” is the representation of “user story”, and “FP” is the representation of “functional process”. For example, “IT1-US5-FP1” is used for the first functional process of fifth user story of first iteration for film renting project.

4.4. Application of COSMIC Measurement Method

COSMIC measurement method [17, 18] needs to be applied to each identified functional process. Procedure for applying the COSMIC measurement method is already described in Subsection 2.2.1 and Section 3.3, so it is not described again.

After functional processes of each user story are identified, their sizes in terms of CFPs are measured by using COSMIC measurement method. Since all three iterations for film renting project is performed with different level of information, measurement results may change for some user stories from iteration to iteration.

Since there are three iterations and too many user stories with many functional processes, it is not very logical to present the measurement details of all of them. For this reason, measurement details of just one iteration of one user story is shown here. In fact there are three measurements since there are three iterations, however, just the first iteration is presented with all details. Remaining iterations of that user story and all other user stories are presented in Appendix A⁶.

4.4.1. COSMIC Measurement Details of a Single Iteration of a Single User Story

As mentioned previously, there are three iterations for the film renting project. Measurement details of the first iteration of first user story is given here. In the second

⁶The first iteration of the user story which is measured in Section 4.4 is presented with all details; however, the measurements in Appendix A are not presented as detailed as this one. The reason is, all measurements are implemented similarly, and if all detailed explanations were included in Appendix A, it would be too long for the thesis.

and third iterations, some missing information are provided, and new requirements of the user arise, however, just first iteration is described here with all details. Remaining iterations are presented in Appendix A, as mentioned previously.

The presentation of the measurement details has a constant format so that this format is obeyed during the measurement. The required items for this format are as follows:

- A table to present the high level information of the user story which is measured. This table includes:
 - (i) Identifier: Unique alias of the user story.
 - (ii) User Story: Definition of the user story.
 - (iii) Functional Processes: Identified functional processes of the user story.
 - (iv) Questions and Answers/Assumptions (optional): User story related questions that arise in case of missing information, and the answers (if available) to those questions or assumptions about the answers of those questions.
- A separate table for each functional process of the user story which is measured to present the measurement details. These tables include:
 - (i) Identifier: Unique alias of the functional process.
 - (ii) Functional Process: Definition of the functional process.
 - (iii) Questions and Answers/Assumptions (optional): Functional process related questions that arise in case of missing information, and the answers (if available) to those questions or assumptions about the answers of those questions.
 - (iv) Entry DMs: Entry data movements (DM) of the functional process. Each Entry data movement is represented in a separate row.
 - (v) Read DMs: Read data movements of the functional process. Each Read data movement is represented in a separate row.
 - (vi) Write DMs: Write data movements of the functional process. Each Read data movement is represented in a separate row.
 - (vii) Exit DMs: Exit data movements of the functional process. Each Exit data movement is represented in a separate row.

- A table to present the results of the measurement of the user story. This table includes:
 - (i) Identifier: Unique alias of the user story.
 - (ii) User Story: Definition of the user story.
 - (iii) Functional Processes: Functional processes of the user story with measurement results for each type of data movement (Entry, Read, Write, Exit).
 - (iv) Size (CFP): Size of the user story in terms of CFPs. This value is calculated by adding up all data movements of each functional process of the user story.

Measurement details of the first iteration of the first user story are described in Table 4.3, Table 4.4, and Table 4.5. Table 4.3 includes the high level information about the user story.

Table 4.3. High level information of the first user story for first iteration

Identifier	IT1-US1	
User Story	As a customer I want to be able to rent a film so that I can watch it at my home.	
Functional Processes	IT1-US1-FP1	Customers can rent films on-site.
Questions and Answers/ Assumptions	<i>Is it only possible to rent a film on-site or do other possibilities like renting via internet exist?</i> First iteration does not have clear information about different possibilities of renting a film. For this reason, it is assumed that on-site is the only possibility to rent a film.	

It can be seen from Table 4.3 that, one functional process is identified in the user story, and some assumptions are provided for missing information.

Table 4.4 includes the measurement details of the identified functional process of the user story for first iteration.

Table 4.4. Measurement details of the functional process of user story

Identifier	IT1-US1-FP1
Functional Process	Customers can rent films on-site.
Questions and Answers/ Assumptions	<i>What kind of information needs to be provided to rent a film on-site?</i> First iteration does not have clear information about the needed information for renting a film on-site. For this reason, it is assumed that basic customer information, film information, and price information are needed.
Entry DMs	<i>(i) Customer Information</i> In order to represent the customer who is renting a film, customer information needs to be captured by the system. If a customer is already has an account in the system, just ID of the customer is enough to be captured. However, if customer does not have an account, all detailed information of the customer is needed. In any case, customer information needs to be captured by the system.
	<i>(ii) Film Information</i> In order to represent the film which is being rented by the customer, film information needs to be captured by the system. ID of the film may be taken directly by using an automatic mechanism like barcode reader. But if there is any problem with the barcode number, additional information (like film name) may be needed to be entered manually. In any case, film information needs to be captured by the system.
	<i>(iii) Price Information</i> Price of the film can normally be read from the system automatically. However, in on-site renting operation, it is possible that the price may be entered by the employees. So, price information needs to be captured by the system.

Table continued on next page

Table 4.4. Measurement details of the functional process of user story (cont'd)

Read DMs	<i>(i) Customer Information</i> In order to get the details about the customer for the output report, it is needed to read the customer information from a persistent storage. So, after the customer information is entered into the system, additional information for the customer needs to be read from the system with one Read data movement.
	<i>(ii) Film Information</i> After basic film information is entered into the system, additional information needs to be read from the persistent storage. This additional information most importantly includes the availability of the film, because after a request comes for any film, its availability must be controlled.
	<i>(iii) Price Information</i> In case the price is not provided manually, price of the film needs to be captured automatically from the system. For this reason, a read operation is needed from a persistent storage. This price information can then be used for calculating the total cost of the operation.
Write DMs	<i>(i) Customer Information</i> Customer information, who is renting a film, needs to be saved into a persistent storage. This information can be helpful for auditing and historical reporting.
	<i>(ii) Film Information</i> Film information, which is being rented by the customer, needs to be saved into a persistent storage. This information can be helpful for auditing and historical reporting.
	<i>(iii) Price Information</i> Price of the film, which is being rented by the customer, needs to be saved into a persistent storage. This information can be helpful for auditing and historical reporting.
Exit DMs	<i>(i) Customer Information</i> After on-site film renting operation completes, a report about the process needs to be generated. This report, like a receipt, includes the customer information. So, one Exit data movement is counted for customer information.

Table continued on next page

Table 4.4. Measurement details of the functional process of user story (cont'd)

	<i>(ii) Film Information:</i> The report which is generated after the on-site renting operation also includes film information. The list of the films which are rented at the operation are included in this report.
	<i>(iii) Price Information</i> Price of the films are also reported, so one Exit data movement is needed for price information.
	<i>(iv) Error Message</i> Error message is the default Exit data movement according to the COSMIC measurement method.

As it can be seen from Table 4.4, some assumptions are provided for missing information. The measurement results of also show that, three Entry data movements, three Read data movements, three Write data movements, and four Exit data movements are needed for this functional process. After this table is prepared, Table 4.5 includes the measurement results of the user story.

Table 4.5. Measurement results of the first user story for first iteration

Identifier	IT1-US1		
User Story	As a customer I want to be able to rent a film so that I can watch it at my home.		
Functional Processes	IT1-US1-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	3
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	4
		<i>Total</i>	13
Size (CFP)			13

According to Table 4.5, size of the first functional process of user story is calculated as 13 CFPs, which is also the size of the user story since there is not any other functional

process of this user story. However, it is important to note that, this is the measurement result of the first iteration. Second and third iterations are also performed on the user story, since missing and additional information is obtained after the first and second iterations.

4.4.2. COSMIC Measurement Results

According to the applied COSMIC measurement method, measurement results of all user stories are obtained in terms of CFPs. The sum of these CFPs gives the overall size of the film renting project. However, as already mentioned previously, three iterations are applied on the film renting project. This means that, there are three calculated overall size values each of which represents the overall effort of different iterations. These three measurement results are represented in three different tables in the thesis:

- A table to present the size of all functional processes for all iterations in terms of CFPs.
- A table to present the size of all user stories for all iterations in terms of CFPs.
- A table to present the number of all type of data movements (Entry, Read, Write, Exit) for all iterations.

Table 4.6 presents the size of all functional processes for all iterations in terms of CFPs. First three columns of Table 4.6 show the sizes of functional processes in terms of CFPs for three iterations. “-” carets indicate that, the functional process does not exist at the related iteration. It can be seen from the table that, total size of the first iteration is calculated as 77 CFPs, total size of the second iteration is calculated as 104 CFPs, and total size of the third iteration is calculated as 127 CFPs. This means that, there is an increment in the total number of CFPs from iteration to iteration. The reason behind this fact is user requirements are continuously changing. Since new requirements are added, and existing requirements are updated in second and third iterations, the measurement results increase at later iterations. This is also valid for each functional process. As new iterations are performed, sizes of the functional

processes are generally increasing. In film renting project, there is just one exception of this implication. That exception is the functional process of fifth user story. Size of that functional process is decreased in the second iteration.

Table 4.6. Measurement results of functional processes for all iterations

	Size 1	Size 2	Size 3	Change 1-2	Change 2-3
US1-FP1	13	13	16	0	3
US1-FP2	-	15	18	15	3
US2-FP1	4	8	8	4	0
US2-FP2	-	-	8	0	8
US3-FP1	9	9	9	0	0
US4-FP1	6	8	12	2	4
US5-FP1	9	8	8	1	0
US6-FP1	6	7	8	1	1
US6-FP2	6	7	8	1	1
US7-FP1	6	7	8	1	1
US7-FP2	6	7	8	1	1
US8-FP1	6	8	8	2	0
US8-FP2	6	7	8	1	1
Total	77	104	127	29	23

Last two columns of Table 4.6 show the absolute change in number of CFPs between different iterations. For instance; for “US1-FP1”, “Change 2-3” (3) is calculated by subtracting “Size 2” (13) from “Size 3” (16). The general formula for calculating “Change” value is shown in Equation (4.1).

$$change(i, x, y) = |CFP_i(y) - CFP_i(x)| \quad (4.1)$$

where, i represents the functional process, x and y represents the iteration number. For example:

$$\begin{aligned} \text{change}(US_1FP_1, IT_2, IT_3) &= |16 - 13| \\ &= 3 \text{ CFPs} \end{aligned}$$

The reason of showing the absolute value is, being able to explore overall change in the number of CFPs. For example, if size of one functional process decreases in one of the iterations, the absolute change number increases. By this way, it is possible to track the number of changes correctly.

Table 4.7. Measurement results of user stories for all iterations

	Size 1	Size 2	Size 3	Change 1-2	Change 2-3
US1	13	28	34	15	6
US2	4	8	16	4	8
US3	9	9	9	0	0
US4	6	8	12	2	4
US5	9	8	8	1	0
US6	12	14	16	2	2
US7	12	14	16	2	2
US8	12	15	16	3	1
Total	77	104	127	29	23

Table 4.7 represents the measurement results with different level of focus. Instead of showing each functional process separately, Table 4.7 shows the sizes of user stories in terms of CFPs. Measurement results of all three iterations are shown in the table. Note that this table shows identical total number of CFPs with Table 4.6, which is an expected behavior. In addition to tables, number of CFP changes for iterations can also be seen in Figure 4.1 which shows number of CFPs per iteration.

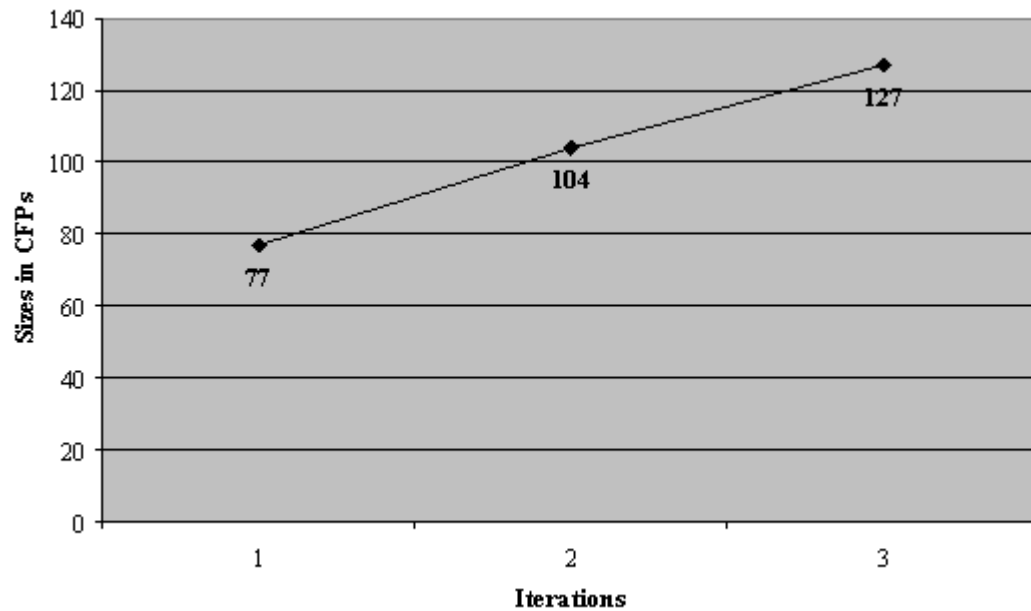


Figure 4.1. Sizes in CFPs per iteration

In addition to provided measurement results, number of data movements of each iteration can be seen in Table 4.8. This table is not related with the functional processes or user stories. Instead, it shows number of types of data movements which are obtained from the measurements. It can be seen from the table that, number of different types of data movements are very close to each other per iteration. For example third iteration has 32 Entry data movements, 31 Read data movements, 33 Write data movements, and 31 Exit data movements. From this information, it can be concluded that, in film renting project all data movement types are distributed very closely for each iteration.

Table 4.8. Number of data movements for all iterations

	Iteration 1	Iteration 2	Iteration 3
Entry Data Movements	22	27	32
Read Data Movements	16	26	31
Write Data Movements	20	27	33
Exit Data Movements	19	24	31
Total	77	104	127

4.5. Application of COSMIC Verification Method

COSMIC verification method [26] needs to be applied to each identified functional process. Procedure for applying the COSMIC verification method is already described in Subsection 2.2.2 and Section 3.4, so it is not described again.

For the film renting project, three iterations are performed as mentioned previously. Since all three iterations are performed with different levels of information, documentation qualities of the functional processes change from iteration to iteration, so that it is important to identify the documentation quality with COSMIC verification method.

By using the identified quality ratings of documentations, it is possible to identify the quality of the COSMIC measurement, because as quality rating increases from (e) to (a), measurements become more reliable. The reason is, if the measurements depend on high quality documentation, it is more likely that user requirements are identified more accurately and thus requirements are measured more correctly.

Quality ratings of the documentations are shown in Table 4.9. The columns of the table represent three iterations whereas rows represent the functional processes of film renting project. It can be seen from the table that, quality ratings are not decreasing from iteration to iteration. For example, second iteration documentation quality of a functional process always equals to or higher than the first iteration. This is also true for the third iteration; third iteration documentation quality of a functional process always equals to or higher than the second and first iterations. The reason is, in later iterations, either new information is gained or existing information is updated so that the quality of the documentation for the functional process does not decrease. Thus, it can be concluded that quality of the documentation has an impact on the measurement results.

Table 4.9. Quality ratings of functional processes for all iterations

	Documentation Quality 1	Documentation Quality 2	Documentation Quality 3
US1-FP1	c	b	a
US1-FP2	d	c	b
US2-FP1	c	b	a
US2-FP2	d	d	b
US3-FP1	b	b	b
US4-FP1	c	b	b
US5-FP1	c	c	b
US6-FP1	c	b	a
US6-FP2	c	b	a
US7-FP1	c	b	a
US7-FP2	c	b	a
US8-FP1	c	b	a
US8-FP2	c	b	a

Table 4.10 shows the percentages of the quality of the documentations according to quality ratings.

Table 4.10. Percentages of quality ratings of functional processes for all iterations

	Iteration 1	Iteration 2	Iteration 3
% a	0	0	62
% b	8	77	38
% c	77	15	0
% d	15	8	0
% e	0	0	0

The graphical representation of the percentages of the quality ratings are displayed in Figure 4.2.

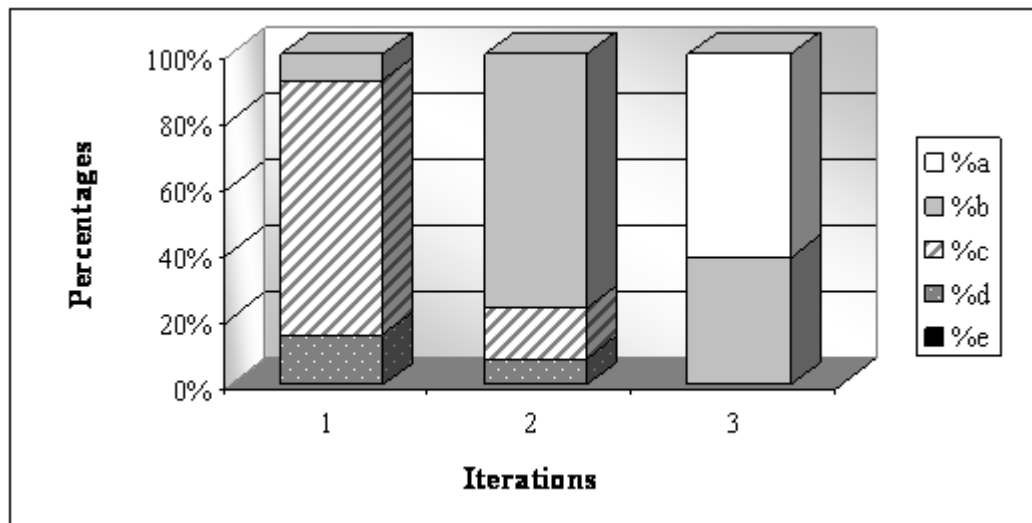


Figure 4.2. Percentages of the quality of the documentations

According to Table 4.10 and Figure 4.2, there is not any (c) or (d) rating at the end of the third iteration, whereas first and second iterations include (c) and (d) ratings. This is the cause of gathering all details of the requirements at later iterations. As it can also be seen, (e) rating does not exist in any of the iterations, and most of the functional processes are rated with (a) at the end of the third step measurements. These results show the reliability of the measurements.

4.6. Calculation of Efforts

In order to prepare project plans, it necessary to calculate the needed effort for projects. Since project managers use these effort values for making scheduling, budget and resource plans, these calculated effort values completely affect the plans of the projects. Even, plans of the projects completely depend on these calculated values.

From this perspective, it is obvious that the approach proposed in this paper is very helpful for planning of projects. The approach not only provides the overall effort needed, but also provides the effort per user story, even per functional process. Thus, it is possible to plan all small pieces of the project by using the proposed approach in

addition to high level overall plan.

The calculation of effort values is already described in Section 3.5 and Section 3.6. The selection of effort per CFP value is made by analyzing the ISBSG repository. Firstly, ISBSG repository is filtered according to the specified criteria. These criteria are determined according to the properties of the film renting project. Criteria used to choose the projects from ISBSG database are as follows:

- Count Approach: COSMIC-FFP
- Development Type: New Development
- Primary Programming Language: Java

After above criteria are applied on the ISBSG repository, and outliers, according to the Normalized Level 1 PDR value of the ISBSG repository, are omitted, nine projects remain. Effort per CFP value for these nine projects is identified as low, average, and high. Results show that low effort per CFP is 0.9 hours/CFP, average is 3.4 hours/CFP, and high is 8.8 hours/CFP. The decision of using which effort per CFP value needs to be made by project managers. In the film renting project, identified average effort per CFP value, which is 3.4 hours/CFP, is used for effort calculations.

All effort values are calculated by using Equation (3.1), Equation (3.2), and Equation (3.3). After needed effort for each functional process is calculated by using Equation (3.1), needed effort for each user story is calculated by using Equation (3.2). Finally, Equation (3.3) is used for calculating the overall effort needed for the project.

Table 4.11 shows the needed effort values for each functional process by using identified average effort per CFP value. From Table 4.11, needed effort for each functional process can be seen separately. However, it is also possible to see the overall effort needed for the project. Since there are three different iterations, there are also three calculated overall effort values. In the first iteration, calculated overall effort value for the film renting project is 261.8 person-hours, in the second iteration it is 353.6 person-hours, and in the third iteration it is 431.8 person-hours.

Table 4.11. Needed efforts for functional processes in person-hour

	Effort 1	Effort 2	Effort 3	Change 1-2	Change 2-3
US1-FP1	44.2	44.2	54.4	0	10.2
US1-FP2	-	51	61.2	51	10.2
US2-FP1	13.6	27.2	27.2	13.6	0
US2-FP2	-	-	27.2	0	27.2
US3-FP1	30.6	30.6	30.6	0	0
US4-FP1	20.4	27.2	40.8	6.8	13.6
US5-FP1	30.6	27.2	27.2	3.4	0
US6-FP1	20.4	23.8	27.2	3.4	3.4
US6-FP2	20.4	23.8	27.2	3.4	3.4
US7-FP1	20.4	23.8	27.2	3.4	3.4
US7-FP2	20.4	23.8	27.2	3.4	3.4
US8-FP1	20.4	27.2	27.2	6.8	0
US8-FP2	20.4	23.8	27.2	3.4	3.4
Total	261.8	353.6	431.8	98.6	78.2

In the table, the most reliable value of the calculated effort is 431.8 person-hours, since it is the result of the final iteration, and it is calculated with higher quality information and documentation.

As in the case of functional processes, needed efforts for user stories are shown in Table 4.12. It can be seen from Table 4.12 that, the total results are identical with Table 4.11 which is an expected behavior.

By using Table 4.12, it is possible for project managers to identify the needed effort values for each separate user story. For this reason, this table also includes valuable information for project planning.

Table 4.12. Needed efforts for user stories in person-hour

	Effort 1	Effort 2	Effort 3	Change 1-2	Change 2-3
US1	44.2	95.2	115.6	51	20.4
US2	13.6	27.2	54.4	13.6	27.2
US3	30.6	30.6	30.6	0	0
US4	20.4	27.2	40.8	6.8	13.6
US5	30.6	27.2	27.2	3.4	0
US6	40.8	47.6	54.4	6.8	6.8
US7	40.8	47.6	54.4	6.8	6.8
US8	40.8	51	54.4	10.2	3.4
Total	261.8	353.6	431.8	98.6	78.2

All in all, overall effort needed for the film renting project is calculated as 431.8 person-hours. By using this information and calculated effort values for each user story (even functional process), project managers can prepare more reliable and maintainable project plans. It is more reliable, because the plan depends on real measurement results, and it is more maintainable because needed effort for each user requirement is calculated separately instead of just having guess estimation on overall effort. Thus, any change in any of the requirements does not require analyzing whole project. Instead, just needed effort for that requirement (user story) needs to be updated, and other parts of the project remain same.

5. CONCLUSION

It is commonly accepted and thought that management of Agile software projects has great amount of uncertainty and unpredictability caused by continuously changing requirements and incomplete requirement identifications in the initialization of the projects. In order to solve those problems, different approaches have been developed, such as Planning Poker and Paired Comparisons by using Incomplete Cyclic Designs. Such approaches are useful; however, guess estimations of project efforts and project plans still depend just on Expert Judgment. As a result of this, project plans are not as reliable and applicable as desired in addition to the hardness of the maintainability of the plans.

The purpose of this thesis is to help tackling difficulties of managing Agile software projects by proposing an improved software planning technique. Problems of different approaches are identified, and a new approach is developed in order to solve the problems.

In the proposed approach, instead of just guess estimation, there is measurement of the size of the product [52]. This measurement is implemented over user stories which are taken during the requirements analysis phase. After user stories are taken, they are measured in terms of COSMIC Function Points by using COSMIC method, and their documentation qualities are identified by using COSMIC verification method. Since these methods are performed on the requirements, it is not needed to wait for the implementation. As a result of application of these methods, needed efforts for the projects are calculated by benefiting from project historical databases. Steps of the proposed approach are as follows:

- (i) Identification of the user requirement for each user story.
- (ii) Discussion on formulation of the user requirements to find functional processes.
- (iii) Measurement of the size (CFP) of each user story with COSMIC measurement method.

- (iv) Determination of quality of the documentation of each user story with COSMIC verification method.
- (v) Discussion on effort per CFP value.
- (vi) Calculation of overall effort by using effort per CFP value.
- (vii) Preparation of project plan according to the calculated effort.
- (viii) Preparation of other iterations of planning by using new information (optional).

After all iterations of measurement are completed, final overall effort of the projects is obtained. Since there are more solid facts like measurement results and identified documentation quality, calculated efforts with the proposed approach are more reliable.

In order to show the applicability, proposed approach is applied on a film renting project. There are eight user stories in the project, and the approach is applied as three iterations with different information. The results show that, by using the proposed approach, sizes of all pieces of the product can be obtained with all details, and by using the measurement results, project plans can be prepared with higher reliability and maintainability. Project plans are more reliable, because they depend on solid measurement results, and they are more maintainable, because size of every piece of the product is measured. So, if any of the requirements changes, instead of estimating the overall effort, just that requirement needs to be measured once more.

In the thesis, choice of the unit effort (effort per CFP) is determined by analyzing the ISBSG repository with specific criteria according to the film renting project. Authors suggest having low, average, and high unit effort based on the data collected from ISBSG and different hypothesis from the measurer. This is not the main topic of the thesis, but of course it is still important for a final accurate global effort.

Additionally it is shown that, documentation quality has an impact on the measurement results. As documentation quality changes, measurement results change by depending on the information in the documentation. It is also presented in the thesis that, quality of the documentation helps to criticize the measurement.

The details of the approach are described in the thesis; however, there may be additional works for improvement of the approach. Firstly, the approach is tested in the thesis with a small project with eight user stories. There is a need to experiment it in the context of a large organization with multiple projects. By measuring each project at different phases, the organization probably copes better with the risk of increment of the sizes of the projects without control. At the same time this approach probably helps large organizations to collect their own project historical databases which reduces the uncertainty for the organization. Secondly the expected behavior is that, if a user story (or functional process) is rated with higher documentation quality, measurement results of that user story are more reliable, because higher documentation quality means more available information with more accuracy. This is presented as an expected behavior; however, it is not proven yet in this thesis.

APPENDIX A: MEASUREMENT DETAILS OF ITERATIONS

Measurement details of three iterations for all user stories and their functional processes are presented here.

A.1. First Iteration

First user story of first iteration is already measured in the thesis. Measurements of the remaining user stories for the first iteration are included here. All functional processes are measured separately, and all details of the measurements are included in the provided tables.

Table A.1. High level information of the second user story for first iteration

Identifier	IT1-US2	
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal so that I can find a film as I wish.	
Functional Processes	IT1-US2-FP1	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to filter the list of films by using on-site terminal or do other possibilities, like filtering via internet, exist?</i> First iteration does not have clear information about possible types of filtering. For this reason, it is assumed that using the on-site terminal is the only possibility for filtering the list of films.	

Table A.2. Measurement details of the first functional process of second user story for first iteration

Identifier	IT1-US2-FP1
Functional Process	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
Questions and Answers/ Assumptions	<i>Can all three parameters (title, director, cast member) be used at the same time for filtering or just one of them can be used?</i> First iteration does not have clear information about filtering operation. For this reason, it is assumed that customers can filter the list of films by using just one of the filtering parameters. They will not be able to use any combination of these parameters together.
	<i>Is authentication of the customer needed for using the filtering option in the terminal?</i> First iteration does not have clear information about the authentication for filtering operation. For this reason, it is assumed that authentication of the customer is not needed to the terminal for filtering the list of films.
	<i>What will be listed as the output of the filtering operation?</i> First iteration does not have clear information about the output of the filtering operation. For this reason, it is assumed that title of the film, director of the film, and all cast members will be listed as output of the operation. Since there is not any distinction between the data groups of these items, it is also assumed that they are all in one data group.
Entry DMs	(i) Film Information
Read DMs	(i) Film Information
Write DMs	-
Exit DMs	(i) Film Information
	(ii) Error Message

Table A.3. Measurement results of the second user story for first iteration

Identifier	IT1-US2		
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal so that I can find a film as I wish.		
Functional Processes	IT1-US2-FP1	<i>Entry Data Movements</i>	1
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	0
		<i>Exit Data Movements</i>	2
		<i>Total</i>	4
Size (CFP)			4

Table A.4. High level information of the third user story for first iteration

Identifier	IT1-US3	
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.	
Functional Processes	IT1-US3-FP1	Customers can criticize the films by using on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to criticize a film by using on-site terminal or do other possibilities, like criticizing via internet, exist?</i> First iteration does not have clear information about criticizing types. For this reason, it is assumed that the criticisms can just be made via on-site terminal.	

Table A.5. Measurement details of the first functional process of third user story for first iteration

Identifier	IT1-US3-FP1
Functional Process	Customers can criticize the films by using on-site terminal.
Questions and Answers/ Assumptions	<i>What type of information can the customers enter into the on-site terminal?</i> First iteration does not have clear information about the types of criticism information. For this reason, it is assumed that criticisms will be presented in the form of text.
	<i>Is authentication of the customer needed for criticizing a film by using on-site terminal?</i> First iteration does not have clear information about the authentication for criticizing a film. For this reason, it is assumed that authentication of the customer is needed to the terminal for criticizing a film.
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Read DMs	(i) Customer Information
	(ii) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Exit DMs	(i) Error Message

Table A.6. Measurement results of the third user story for first iteration

Identifier	IT1-US3		
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.		
Functional Processes	IT1-US3-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	1
		<i>Total</i>	9
Size (CFP)			9

Table A.7. High level information of the fourth user story for first iteration

Identifier	1-US4	
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.	
Functional Processes	IT1-US4-FP1	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to view the criticisms on-site or do other possibilities, like remote viewing via internet, exist?</i> First iteration does not have clear information about accessibility options to the criticisms. For this reason, it is assumed that criticisms can just be reached via on-site terminal.	

Table A.8. Measurement details of the first functional process of fourth user story for first iteration

Identifier	IT1-US4-FP1
Functional Process	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>What type of information for criticisms can the customers obtain from the on-site terminal?</i> First iteration does not have clear information about the types of information. For this reason, it is assumed that criticisms will be presented in the form of text.
	<i>Will the owners of the criticisms be visible to the customers?</i> First iteration does not have clear information about visibility of the criticism owners. For this reason, it is assumed that owners of the criticisms will not be visible to the customers. Criticisms will be anonymous.
	<i>Is authentication of the customer needed for viewing the criticisms via on-site terminal?</i> First iteration does not have clear information about the authentication for viewing criticisms. For this reason, it is assumed that customers do not need to login to the system for viewing criticisms.
Entry DMs	(i) Film Information
Read DMs	(i) Film Information
	(ii) Criticism Information
Write DMs	-
Exit DMs	(i) Film Information
	(ii) Criticism Information
	(iii) Error Message

Table A.9. Measurement results of the fourth user story for first iteration

Identifier	IT1-US4		
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.		
Functional Processes	IT1-US4-FP1	<i>Entry Data Movements</i>	1
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	0
		<i>Exit Data Movements</i>	3
		<i>Total</i>	6
Size (CFP)			6

Table A.10. High level information of the fifth user story for first iteration

Identifier	IT1-US5	
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.	
Functional Processes	IT1-US5-FP1	Customers can raise a request for a nonexistent film on-site.
Questions and Answers/ Assumptions	<i>Is it only possible to raise a request on-site or do other possibilities, like raising a request via internet, exist?</i> In the first iteration, it is clearly stated that on-site is the only possibility for raising a request for a nonexistent film.	

Table A.11. Measurement details of the first functional process of fifth user story for first iteration

Identifier	IT1-US5-FP1
Functional Process	Customers can raise a request for a nonexistent film on-site.
Questions and Answers/ Assumptions	<i>Is there a limit on the number of films that can be requested at one attempt?</i> First iteration does not have clear information about raising a film request. For this reason, it is assumed that customers can raise a request just for one film at one attempt.
	<i>Is the payment of the film which is requested by the customer being done at the time of request or at the time of taking it?</i> First iteration does not have clear information about the time of the payment for requested film. For this reason, it is assumed that the payment will be done at the time of taking it.
Entry DMs	(i) Customer Information
	(ii) Film Information
Read DMs	(i) Customer Information
	(ii) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Error Message

Table A.12. Measurement results of the fifth user story for first iteration

Identifier	IT1-US5		
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.		
Functional Processes	IT1-US5-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	3
		<i>Total</i>	9
Size (CFP)			9

Table A.13. High level information of the sixth user story for first iteration

Identifier	IT1-US6	
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.	
Functional Processes	IT1-US6-FP1	Employees can add a film into the system.
	IT1-US6-FP2	Employees can delete a film from the system.

Table A.14. Measurement details of the first functional process of sixth user story for first iteration

Identifier	IT1-US6-FP1
Functional Process	Employees can add a film into the system.
Questions and Answers/ Assumptions	<i>What kind of information is needed for adding a new film into the system?</i> First iteration does not have clear information about the needed information to add a new film into the system. For this reason, it is assumed that basic film information is needed in addition to the administrator information who adds the film.
	<i>Can all administrators add a film into the system or is there any specific administrator who can access the film database?</i> First iteration does not have clear information about the administrator privileges. It is assumed that all administrators can add films into the system.
	<i>Will there be an output report after new film is added into the system?</i> First iteration does not have clear information about the output report of the film addition operation. For this reason, it is assumed that there will not be any output reports.
Entry DMs	(i) Film Information
	(ii) Administrator Information
Read DMs	(i) Film Information
Write DMs	(i) Film Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.15. Measurement details of the second functional process of sixth user story for first iteration

Identifier	IT1-US6-FP2
Functional Process	Employees can delete a film from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete a film from the system or is there any specific administrator who can access the film database?</i> First iteration does not have clear information about the administrator privileges. For this reason, it is assumed that all administrators can delete films from the system.</p> <p><i>Will there be output report after film is deleted from the system?</i> First iteration does not have clear information about the output report. So, it is assumed there will not be any output reports.</p>
Entry DMs	<p>(i) Film Information</p> <p>(ii) Administrator Information</p>
Read DMs	(i) Film Information
Write DMs	<p>(i) Film Information</p> <p>(ii) Administrator Information</p>
Exit DMs	(i) Error Message

Table A.16. Measurement results of the sixth user story for first iteration

Identifier	IT1-US6		
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.		
Functional Processes	IT1-US6-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
	IT1-US6-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
Size (CFP)			12

Table A.17. High level information of the seventh user story for first iteration

Identifier	IT1-US7	
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.	
Functional Processes	IT1-US7-FP1	Employees can add a customer into the system.
	IT1-US7-FP2	Employees can delete a customer from the system.

Table A.18. Measurement details of the first functional process of seventh user story for first iteration

Identifier	IT1- US7-FP1
Functional Process	Employees can add a customer into the system.
Questions and Answers/ Assumptions	<i>What kind of information is needed for adding a new customer into the system?</i> First iteration does not have clear information about the needed information to add a new customer into the system. For this reason, it is assumed that basic customer information is needed in addition to the administrator information who adds the customer.
	<i>Can all administrators add a customer into the system or is there any specific administrator who can access the customer database?</i> First iteration does not have clear information about the administrator privileges. It is assumed that all administrators can add customers into the system.
	<i>Will there be an output report after the new customer is added into the system?</i> First iteration does not have clear information about the output report of the customer addition operation. For this reason, it is assumed that there will not be any output reports.
Entry DMs	(i) Customer Information
	(ii) Administrator Information
Read DMs	(i) Customer Information
Write DMs	(i) Customer Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.19. Measurement details of the second functional process of seventh user story
for first iteration

Identifier	IT1- US7-FP2
Functional Process	Employees can delete a customer from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete customers from the system or is there any specific administrator who can access the customer database?</i></p> <p>First iteration does not have clear information about the administrator privileges. For this reason, it is assumed that all administrators can delete customers from the system.</p> <hr/> <p><i>Will there be an output report after the customer is deleted from the system?</i> First iteration does not have clear information about the output report of the customer deletion operation. For this reason, it is assumed that there will not be any output reports.</p>
Entry DMs	<p>(i) Customer Information</p> <hr/> <p>(ii) Administrator Information</p>
Read DMs	(i) Customer Information
Write DMs	<p>(i) Customer Information</p> <hr/> <p>(ii) Administrator Information</p>
Exit DMs	(i) Error Message

Table A.20. Measurement results of the seventh user story for first iteration

Identifier	IT1-US7		
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.		
Functional Processes	IT1-US7-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
	IT1-US7-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
Size (CFP)			12

Table A.21. High level information of the eighth user story for first iteration

Identifier	IT1-US8	
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.	
Functional Processes	IT1-US8-FP1	Employees can add a promotion into the system.
	IT1-US8-FP2	Employees can delete a promotion from the system.

Table A.22. Measurement details of the first functional process of eighth user story for first iteration

Identifier	IT1- US8-FP1
Functional Process	Employees can add a promotion into the system.
Questions and Answers/ Assumptions	<i>What information is needed to enter a new promotion into the system?</i> First iteration does not have clear information about the needed information to add promotions. For this reason, it is assumed that the promotions which are entered into the system must have description, begin and end date, and discount amount. It is also assumed that all these information are stored in one data group.
	<i>Will the promotions be valid for all of the customers or just for a group of customers?</i> First iteration does not have clear information about the customer groups to which the promotions will be applicable. For this reason, it is assumed that the promotions will be valid for all customers.
Entry DMs	(i) Promotion Information
	(ii) Administrator Information
Read DMs	(i) Promotion Information
Write DMs	(i) Promotion Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.23. Measurement details of the second functional process of eighth user story for first iteration

Identifier	IT1- US8-FP2
Functional Process	Employees can delete a promotion from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete promotions from the system or is there any specific administrator who can access the promotion database?</i> First iteration does not have clear information about the administrator privileges. For this reason, it is assumed that all administrators can delete promotions from the system.</p> <p><i>Will there be an output report after the promotion is deleted from the system?</i> First iteration does not have clear information about the output report of the promotion deletion operation. For this reason, it is assumed that there will not be any output reports.</p>
Entry DMs	<p>(i) Promotion Information</p> <p>(ii) Administrator Information</p>
Read DMs	(i) Promotion Information
Write DMs	<p>(i) Promotion Information</p> <p>(ii) Administrator Information</p>
Exit DMs	(i) Error Message

Table A.24. Measurement results of the eighth user story for first iteration

Identifier	IT1-US8		
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.		
Functional Processes	IT1-US8-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
	IT1-US8-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	6
Size (CFP)			12

A.2. Second Iteration

Measurements of all user stories for the second iteration are included here. All functional processes are measured separately, and all details of the measurements are included in the provided tables.

Table A.25. High level information of the first user story for second iteration

Identifier	IT2-US1	
User Story	As a customer I want to be able to rent a film on-site or remotely via internet so that I can watch it at my home.	
Functional Processes	IT2-US1-FP1	Customers can rent films on-site.
	IT2-US1-FP2	Customers can rent films remotely via internet.
Questions and Answers/ Assumptions	<i>Is it only possible to rent a film on-site or do other possibilities like renting via internet exist?</i> In the second iteration, it is clearly stated that it is also possible to rent a film via internet.	

Table A.26. Measurement details of the first functional process of first user story for second iteration

Identifier	IT2-US1-FP1
Functional Process	Customers can rent films on-site.
Questions and Answers/ Assumptions	<i>What kind of information needs to be provided to rent a film on-site?</i> In the second iteration, it is clearly stated that needed information are, customer information, film information, and price information.
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
Read DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Error Message

Table A.27. Measurement details of the second functional process of first user story for second iteration

Identifier	IT2-US1-FP2
Functional Process	Customers can rent films on-site.
Questions and Answers/ Assumptions	<i>What kind of information is needed to rent a film remotely via internet?</i> Second iteration does not have clear information about remote renting operation via internet. For this reason, it is assumed that information about the customer, information about the film, and information about the credit card is needed.
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
Read DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
	(iv) Price Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
	(iv) Price Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Error Message

Table A.28. Measurement results of the first user story for second iteration

Identifier	IT2-US1		
User Story	As a customer I want to be able to rent a film on-site or remotely via internet so that I can watch it at my home.		
Functional Processes	IT2-US1-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	3
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	4
		<i>Total</i>	13
	IT2-US1-FP2	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	4
		<i>Write Data Movements</i>	4
		<i>Exit Data Movements</i>	4
		<i>Total</i>	15
Size (CFP)			28

Table A.29. High level information of the second user story for second iteration

Identifier	IT2-US2	
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal so that I can find a film as I wish.	
Functional Processes	IT2-US2-FP1	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to filter the list of films by using on-site terminal or do other possibilities, like filtering via internet, exist?</i> Second iteration does not have clear information about possible types of filtering. For this reason, assumptions of first iteration still apply.	

Table A.30. Measurement details of the first functional process of second user story for second iteration

Identifier	IT2-US2-FP1
Functional Process	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
Questions and Answers/ Assumptions	<i>Can all three parameters (title, director, cast member) be used at the same time for filtering or just one of them can be used?</i> In the second iteration, it is clearly stated that all three parameters may be used at the same time for filtering purposes. So, assumption of first iteration for this question became invalid in the second iteration.
	<i>Is authentication of the customer needed for using the filtering option in the terminal?</i> In the second iteration, it is clearly stated that user needs to login to the system to use the filtering option, because the operations of the customer need to be saved into a persistent storage for historical reporting.
	<i>What will be listed as the output of the filtering operation?</i> Second iteration does not have clear information about the possible types of filtering. For this reason, assumptions of first iteration still apply.
Entry DMs	(i) Film Information
	(ii) Customer Information
Read DMs	(i) Film Information
	(ii) Customer Information
Write DMs	(i) Film Information
	(ii) Customer Information
Exit DMs	(i) Film Information
	(ii) Error Message

Table A.31. Measurement results of the second user story for second iteration

Identifier	IT2-US2		
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal so that I can find a film as I wish.		
Functional Processes	IT2-US2-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
Size (CFP)			8

Table A.32. High level information of the third user story for second iteration

Identifier	IT2-US3	
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.	
Functional Processes	IT2-US3-FP1	Customers can criticize the films by using on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to criticize a film by using on-site terminal or do other possibilities, like criticizing via internet, exist?</i> Second iteration does not have clear information about criticizing types. For this reason, assumptions of first iteration still apply.	

Table A.33. Measurement details of the first functional process of third user story for second iteration

Identifier	IT2-US3-FP1
Functional Process	Customers can criticize the films by using on-site terminal.
Questions and Answers/ Assumptions	<p><i>What type of information can the customers enter into the on-site terminal?</i> In the second iteration, it is clearly stated that it is only possible to criticize films in the form of text. Sound, video or other types are not valid.</p> <p><i>Is authentication of the customer needed for criticizing a film by using on-site terminal?</i> In the second iteration, it is clearly stated that authentication of the customer is needed for criticizing films.</p>
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Read DMs	(i) Customer Information
	(ii) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Exit DMs	(i) Error Message

Table A.34. Measurement results of the third user story for second iteration

Identifier	IT2-US3		
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.		
Functional Processes	IT2-US3-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	1
		<i>Total</i>	9
Size (CFP)			9

Table A.35. High level information of the fourth user story for second iteration

Identifier	IT2-US4	
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.	
Functional Processes	IT2-US4-FP1	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to view the criticisms on-site or do other possibilities, like remote viewing via internet, exist?</i> Second iteration does not have clear information about the accessibility options to the criticisms. For this reason, assumptions of first step still apply.	

Table A.36. Measurement details of the first functional process of fourth user story for second iteration

Identifier	IT2-US4-FP1
Functional Process	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>What type of information for criticisms can the customers obtain from the on-site terminal?</i> In the second iteration, it is clearly stated that it is only possible to obtain the criticisms about films in the form of text. Sound, video or other types are not valid.
	<i>Will the owners of the criticisms be visible to the customers?</i> In the second iteration, it is clearly stated that owners of the criticisms will be visible to the customers.
	<i>Is authentication of the customer needed for viewing the criticisms via on-site terminal?</i> Second iteration does not have clear information about the authentication for viewing criticisms. For this reason, assumptions of first iteration still apply.
Entry DMs	(i) Film Information
Read DMs	(i) Film Information
	(ii) Criticism Information
	(iii) Criticism Owner Information
Write DMs	-
Exit DMs	(i) Film Information
	(ii) Criticism Information
	(iii) Criticism Owner Information
	(iv) Error Message

Table A.37. Measurement results of the fourth user story for second iteration

Identifier	IT2-US4		
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.		
Functional Processes	IT2-US4-FP1	<i>Entry Data Movements</i>	1
		<i>Read Data Movements</i>	3
		<i>Write Data Movements</i>	0
		<i>Exit Data Movements</i>	4
		<i>Total</i>	8
Size (CFP)			8

Table A.38. High level information of the fifth user story for second iteration

Identifier	IT2-US5	
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.	
Functional Processes	IT2-US5-FP1	Customers can raise a request for a nonexistent film on-site.

Table A.39. Measurement details of the first functional process of fifth user story for second iteration

Identifier	IT2-US5-FP1
Functional Process	Customers can raise a request for a nonexistent film on-site.
Questions and Answers/ Assumptions	<i>Is there a limit on the number of films that can be requested at one attempt?</i> In the second iteration, it is clearly stated that there is not any limit for the number of films that can be requested at the same time. For this reason, read operation for the customer information will be omitted.
	<i>Is the payment of the film which is requested by the customer being done at the time of request or at the time of taking it?</i> Second iteration does not have clear information about the time of the payment for requested film. For this reason, assumptions of first iteration still apply.
Entry DMs	(i) Customer Information
	(ii) Film Information
Read DMs	(i) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Error Message

Table A.40. Measurement results of the fifth user story for second iteration

Identifier	IT2-US5		
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.		
Functional Processes	IT2-US5-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	3
		<i>Total</i>	8
Size (CFP)			8

Table A.41. High level information of the sixth user story for second iteration

Identifier	IT2-US6	
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.	
Functional Processes	IT2-US6-FP1	Employees can add a film into the system.
	IT2-US6-FP2	Employees can delete a film from the system.

Table A.42. Measurement details of the first functional process of sixth user story for second iteration

Identifier	IT2-US6-FP1
Functional Process	Employees can add a film into the system.
Questions and Answers/ Assumptions	<i>What kind of information is needed for adding a new film into the system?</i> In the second iteration, it is clearly stated that detailed film information and administrator information will be enough to add a new film into the system.
	<i>Can all administrators add a film into the system or is there any specific administrator who can access the film database?</i> In the second iteration, it is clearly stated that there will be just one administrator who can add new films.
	<i>Will there be an output report after new film is added into the system?</i> Second iteration does not have clear information about the output report of the film addition operation. For this reason, assumptions of first iteration still apply.
Entry DMs	(i) Film Information
	(ii) Administrator Information
Read DMs	(i) Film Information
	(ii) Administrator Information
Write DMs	(i) Film Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.43. Measurement details of the second functional process of sixth user story
for second iteration

Identifier	IT2-US6-FP2
Functional Process	Employees can delete a film from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete a film from the system or is there any specific administrator who can access the film database?</i> In the second iteration, it is clearly stated that there will be just one administrator who can delete films from the system.</p> <p><i>Will there be an output report after the film is deleted from the system?</i> Second iteration does not have clear information about the output report of the film deletion operation. For this reason, it is assumed that there will not be any output reports.</p>
Entry DMs	<p>(i) Film Information</p> <p>(ii) Administrator Information</p>
Read DMs	<p>(i) Film Information</p> <p>(ii) Administrator Information</p>
Write DMs	<p>(i) Film Information</p> <p>(ii) Administrator Information</p>
Exit DMs	(i) Error Message

Table A.44. Measurement results of the sixth user story for second iteration

Identifier	IT2-US6		
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.		
Functional Processes	IT2-US6-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	7
	IT2-US6-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	7
Size (CFP)			14

Table A.45. High level information of the seventh user story for second iteration

Identifier	IT2-US7	
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.	
Functional Processes	IT2-US7-FP1	Employees can add a customer into the system.
	IT2-US7-FP2	Employees can delete a customer from the system.

Table A.46. Measurement details of the first functional process of seventh user story
for second iteration

Identifier	IT2- US7-FP1
Functional Process	Employees can add a customer into the system.
Questions and Answers/ Assumptions	<i>What kind of information is needed for adding a new customer into the system?</i> In the second iteration, it is clearly stated that detailed customer information and administrator information will be enough to add a new customer into the system.
	<i>Can all administrators add a customer into the system or is there any specific administrator who can access the customer database?</i> In the second iteration, it is clearly stated that there will be just one administrator who can add new customers.
	<i>Will there be an output report after the new customer is added into the system?</i> Second iteration does not have clear information about the output report of the customer addition operation. For this reason, it is assumed that there will not be any output reports.
Entry DMs	(i) Customer Information
	(ii) Administrator Information
Read DMs	(i) Customer Information
	(ii) Administrator Information
Write DMs	(i) Customer Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.47. Measurement details of the second functional process of seventh user story
for second iteration

Identifier	IT2-US7-FP2
Functional Process	Employees can delete a customer from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete customers from the system or is there any specific administrator who can access the customer database?</i></p> <p>In the second iteration, it is clearly stated that there will be just one administrator who can delete customers from the system.</p> <p><i>Will there be an output report after the customer is deleted from the system?</i> Second iteration does not have clear information about the output report of the customer deletion operation. For this reason, it is assumed that there will not be any output reports.</p>
Entry DMs	(i) Customer Information
	(ii) Administrator Information
Read DMs	(i) Customer Information
	(ii) Administrator Information
Write DMs	(i) Customer Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.48. Measurement results of the seventh user story for second iteration

Identifier	IT2-US7		
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.		
Functional Processes	IT2-US7-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	7
	IT2-US7-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	7
Size (CFP)			14

Table A.49. High level information of the eighth user story for second iteration

Identifier	IT2-US8	
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.	
Functional Processes	IT2-US8-FP1	Employees can add a promotion into the system.
	IT2-US8-FP2	Employees can delete a promotion from the system.

Table A.50. Measurement details of the first functional process of eighth user story for second iteration

Identifier	IT2-US8-FP1
Functional Process	Employees can add a promotion into the system.
Questions and Answers/ Assumptions	<i>What information is needed to enter a new promotion into the system?</i> Second iteration does not have clear information about the needed information for adding new promotion. For this reason, assumptions of first iteration still apply.
	<i>Will the promotions be valid for all of the customers or just for a group of customers?</i> In the second iteration, it is clearly stated that promotions will be applied to specific customer groups.
Entry DMs	(i) Promotion Information
	(ii) Administrator Information
	(iii) Customer Group Information
Read DMs	(i) Promotion Information
Write DMs	(i) Promotion Information
	(ii) Administrator Information
	(iii) Customer Group Information
Exit DMs	(i) Error Message

Table A.51. Measurement details of the second functional process of eighth user story
for second iteration

Identifier	IT2- US8-FP2
Functional Process	Employees can delete a promotion from the system.
Questions and Answers/ Assumptions	<p><i>Can all administrators delete promotions from the system or is there any specific administrator who can access the promotion database?</i> In the second iteration, it is clearly stated that there will be just one administrator who can delete promotions from the system.</p> <p><i>Will there be an output report after the promotion is deleted from the system?</i> Second iteration does not have clear information about the output report of the promotion deletion operation. For this reason, it is assumed that there will not be any output reports.</p>
Entry DMs	(i) Promotion Information
	(ii) Administrator Information
Read DMs	(i) Promotion Information
	(ii) Administrator Information
Write DMs	(i) Promotion Information
	(ii) Administrator Information
Exit DMs	(i) Error Message

Table A.52. Measurement results of the eighth user story for second iteration

Identifier	IT2-US8		
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.		
Functional Processes	IT2-US8-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	1
		<i>Total</i>	8
	IT2-US8-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	1
		<i>Total</i>	7
Size (CFP)			15

A.3. Third Iteration

Measurements of all user stories for the third iteration are included here. All functional processes are measured separately, and all details of the measurements are included in the provided tables.

Table A.53. High level information of the first user story for third iteration

Identifier	IT3-US1	
User Story	As a customer I want to be able to rent a film on-site or remotely via internet by benefiting from promotions if possible so that I can watch it at my home.	
Functional Processes	IT3-US1-FP1	Customers can rent films on-site by benefiting from promotions if possible.
	IT3-US1-FP2	Customers can rent films remotely via internet by benefiting from promotions if possible.

Table A.54. Measurement details of the first functional process of first user story for third iteration

Identifier	IT3-US1-FP1
Functional Process	Customers can rent films on-site by benefiting from promotions if possible.
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Promotion Information
Read DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Promotion Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Promotion Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Error Message

Table A.55. Measurement details of the second functional process of first user story for third iteration

Identifier	IT3-US1-FP2
Functional Process	Customers can rent films remotely via internet by benefiting from promotions if possible
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
	(iv) Promotion Information
Read DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
	(iv) Price Information
	(v) Promotion Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Credit Card Information
	(iv) Price Information
	(v) Promotion Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Price Information
	(iv) Error Message

Table A.56. Measurement results of the first user story for third iteration

Identifier	IT3-US1		
User Story	As a customer I want to be able to rent a film on-site or remotely via internet by benefiting from promotions if possible so that I can watch it at my home.		
Functional Processes	IT3-US1-FP1	<i>Entry Data Movements</i>	4
		<i>Read Data Movements</i>	4
		<i>Write Data Movements</i>	4
		<i>Exit Data Movements</i>	4
		<i>Total</i>	16
	IT3-US1-FP2	<i>Entry Data Movements</i>	4
		<i>Read Data Movements</i>	5
		<i>Write Data Movements</i>	5
		<i>Exit Data Movements</i>	4
		<i>Total</i>	18
Size (CFP)			34

Table A.57. High level information of the second user story for third iteration

Identifier	IT3-US2	
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal or remotely via internet so that I can find a film as I wish.	
Functional Processes	IT3-US2-FP1	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
	IT3-US2-FP2	Customers can filter the list of films by title, director, or cast member remotely via internet.
Questions and Answers/ Assumptions	<i>Is it only possible to filter the list of films by using on-site terminal or do other possibilities, like filtering via internet, exist?</i> In the third iteration, it is clearly stated that list of films can also be filtered remotely via internet.	

Table A.58. Measurement details of the first functional process of second user story for third iteration

Identifier	IT3-US2-FP1
Functional Process	Customers can filter the list of films by title, director, or cast member by using on-site terminal.
Questions and Answers/ Assumptions	<i>What will be listed as the output of the filtering operation?</i> In the third iteration, it is clearly stated that title of the film, director of the film, and all cast members will be listed as output of the operation, and they are all in one data group.
Entry DMs	(i) Film Information
	(ii) Customer Information
Read DMs	(i) Film Information
	(ii) Customer Information
Write DMs	(i) Film Information
	(ii) Customer Information
Exit DMs	(i) Film Information
	(ii) Error Message

Table A.59. Measurement details of the second functional process of second user story for third iteration

Identifier	IT3-US2-FP2
Functional Process	Customers can filter the list of films by title, director, or cast member remotely via internet.
Entry DMs	(i) Film Information
	(ii) Customer Information
Read DMs	(i) Film Information
	(ii) Customer Information
Write DMs	(i) Film Information
	(ii) Customer Information
Exit DMs	(i) Film Information
	(ii) Error Message

Table A.60. Measurement results of the second user story of third iteration

Identifier	IT3-US2		
User Story	As a customer, I want to be able to filter the list of films by title, director or cast member by using on-site terminal or remotely via internet so that I can find a film as I wish.		
Functional Processes	IT3-US2-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
	IT3-US2-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
Size (CFP)			16

Table A.61. High level information of the third user story for third iteration

Identifier	IT3-US3	
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.	
Functional Processes	IT3-US3-FP1	Customers can criticize the films by using on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to criticize a film by using on-site terminal or do other possibilities, like criticizing via internet, exist?</i> In the third iteration, it is clearly stated that there will not be any other option for criticizing the films except using on-site terminal.	

Table A.62. Measurement details of the first functional process of third user story for third iteration

Identifier	IT3-US3-FP1
Functional Process	Customers can criticize the films by using on-site terminal.
Entry DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Read DMs	(i) Customer Information
	(ii) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
	(iii) Criticism Information
Exit DMs	(i) Error Message

Table A.63. Measurement results of the third user story for third iteration

Identifier	IT3-US3		
User Story	As a customer, I want to be able to criticize a film by using on-site terminal so that I can share my thoughts about the film with other customers.		
Functional Processes	IT3-US3-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	1
		<i>Total</i>	9
Size (CFP)			9

Table A.64. High level information of the fourth user story for third iteration

Identifier	IT3-US4	
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.	
Functional Processes	IT3-US4-FP1	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>Is it only possible to view the criticisms on-site or do other possibilities, like remote viewing via internet, exist?</i> In the third iteration, it is clearly stated that there is not any other option for accessing the criticisms except using on-site terminal.	

Table A.65. Measurement details of the first functional process of fourth user story for third iteration

Identifier	IT3-US4-FP1
Functional Process	Customers can view criticism of films via on-site terminal.
Questions and Answers/ Assumptions	<i>Is authentication of the customer needed for viewing the criticisms via on-site terminal?</i> In the third iteration, it is clearly stated that customers need to login to the system in order to view the criticisms about the films. Also, operations of the logged in customers will be saved into a persistent storage.
Entry DMs	(i) Film Information
	(ii) Customer Information
Read DMs	(i) Film Information
	(ii) Criticism Information
	(iii) Criticism Owner Information
	(iv) Customer Information
Write DMs	(i) Film Information
	(ii) Customer Information
Exit DMs	(i) Film Information
	(ii) Criticism Information
	(iii) Criticism Owner Information
	(iv) Error Message

Table A.66. Measurement results of the fourth user story for third iteration

Identifier	IT3-US4		
User Story	As a customer, I want to be able to view criticisms of a film, which are shared by other customers, by using on-site terminal so that I can make my decision on renting the film.		
Functional Processes	IT3-US4-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	4
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	4
		<i>Total</i>	12
Size (CFP)			12

Table A.67. High level information of the fifth user story for third iteration

Identifier	IT3-US5	
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.	
Functional Processes	IT3-US5-FP1	Customers can raise a request for a nonexistent film on-site.

Table A.68. Measurement details of the first functional process of fifth user story for third iteration

Identifier	IT3-US5-FP1
Functional Process	Customers can raise a request for a nonexistent film on-site.
Questions and Answers/ Assumptions	<i>Is the payment of the film which is requested by the customer being done at the time of request or at the time of taking it?</i> In the third iteration, it is clearly stated that payment of the film will be made at the time of taking it.
Entry DMs	(i) Customer Information
	(ii) Film Information
Read DMs	(i) Film Information
Write DMs	(i) Customer Information
	(ii) Film Information
Exit DMs	(i) Customer Information
	(ii) Film Information
	(iii) Error Message

Table A.69. Measurement results of the fifth user story for third iteration

Identifier	IT3-US5		
User Story	As a customer, I want to be able to raise a request for a nonexistent film on-site so that I can rent it when it arrives.		
Functional Processes	IT3-US5-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	3
		<i>Total</i>	8
Size (CFP)			8

Table A.70. High level information of the sixth user story of third iteration

Identifier	IT3-US6	
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.	
Functional Processes	IT3-US6-FP1	Employees can add a film into the system.
	IT3-US6-FP2	Employees can delete a film from the system.

Table A.71. Measurement details of the first functional process of sixth user story for third iteration

Identifier	IT3-US6-FP1	
Functional Process	Employees can add a film into the system.	
Questions and Answers/ Assumptions	<i>Will there be an output report after new film is added into the system?</i> In the third iteration, it is clearly stated that there will be an output report which includes the operation details. Detailed information of the added film will be displayed as output.	
Entry DMs	(i) Film Information	
	(ii) Administrator Information	
Read DMs	(i) Film Information	
	(ii) Administrator Information	
Write DMs	(i) Film Information	
	(ii) Administrator Information	
Exit DMs	(i) Error Message	
	(ii) Film Information	

Table A.72. Measurement details of the second functional process of sixth user story for third iteration

Identifier	IT3-US6-FP2
Functional Process	Employees can delete a film from the system.
Questions and Answers/ Assumptions	<i>Will there be an output report after the film is deleted from the system?</i> In the third iteration, it is clearly stated that there will be an output report which includes the operation details. Detailed information of the deleted film will be displayed as output.
Entry DMs	(i) Film Information
	(ii) Administrator Information
Read DMs	(i) Film Information
	(ii) Administrator Information
Write DMs	(i) Film Information
	(ii) Administrator Information
Exit DMs	(i) Error Message
	(ii) Film Information

Table A.73. Measurement results of the sixth user story for third iteration

Identifier	IT3-US6		
User Story	As an employee, I want to be able to add or delete a film so that I can keep the list of films up-to-date.		
Functional Processes	IT3-US6-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
	IT3-US6-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
Size (CFP)			16

Table A.74. High level information of the seventh user story for third iteration

Identifier	IT3-US7	
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.	
Functional Processes	IT3-US7-FP1	Employees can add a customer into the system.
	IT3-US7-FP2	Employees can delete a customer from the system.

Table A.75. Measurement details of the first functional process of seventh user story for third iteration

Identifier	IT3- US7-FP1
Functional Process	Employees can add a customer into the system.
Questions and Answers/ Assumptions	<i>Will there be an output report after the new customer is added into the system?</i> In the third iteration, it is clearly stated that there will be an output report which includes the operation details. Detailed information of the added customer will be displayed as output.
Entry DMs	(i) Customer Information
	(ii) Administrator Information
Read DMs	(i) Customer Information
	(ii) Administrator Information
Write DMs	(i) Customer Information
	(ii) Administrator Information
Exit DMs	(i) Error Message
	(ii) Customer Information

Table A.76. Measurement details of the second functional process of seventh user story
for third iteration

Identifier	IT3- US7-FP2
Functional Process	Employees can delete a customer from the system.
Questions and Answers/ Assumptions	<i>Will there be an output report after the customer is deleted from the system?</i> In the third iteration, it is clearly stated that there will be an output report which includes the operation details. Detailed information of the deleted customer will be displayed as output.
Entry DMs	(i) Customer Information
	(ii) Administrator Information
Read DMs	(i) Customer Information
	(ii) Administrator Information
Write DMs	(i) Customer Information
	(ii) Administrator Information
Exit DMs	(i) Error Message
	(ii) Customer Information

Table A.77. Measurement results of the seventh user story for third iteration

Identifier	IT3-US7		
User Story	As an employee, I want to be able to add or delete a customer so that I can keep the list of customers up-to-date.		
Functional Processes	IT3-US7-FP1	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
	IT3-US7-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
Size (CFP)			16

Table A.78. High level information of the eighth user story for third iteration

Identifier	IT3-US8	
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.	
Functional Processes	IT3-US8-FP1	Employees can add a promotion into the system.
	IT3-US8-FP2	Employees can delete a promotion from the system.

Table A.79. Measurement details of the first functional process of eighth user story for third iteration

Identifier	IT3- US8-FP1
Functional Process	Employees can add a promotion into the system.
Questions and Answers/ Assumptions	<i>What information is needed to enter a new promotion into the system?</i> In the third iteration, it is clearly stated that details of the new promotion are needed, and all these information about the promotions will be hold in one data group.
Entry DMs	(i) Promotion Information
	(ii) Administrator Information
	(iii) Customer Group Information
Read DMs	(i) Promotion Information
Write DMs	(i) Promotion Information
	(ii) Administrator Information
	(iii) Customer Group Information
Exit DMs	(i) Error Message

Table A.80. Measurement details of the second functional process of eighth user story
for third iteration

Identifier	IT3- US8-FP2
Functional Process	Employees can delete a promotion from the system.
Questions and Answers/ Assumptions	<i>Will there be an output report after the promotion is deleted from the system?</i> In the third iteration, it is clearly stated that there will be an output report which includes the operation details. Detailed information of the deleted promotion will be displayed as output.
Entry DMs	(i) Promotion Information
	(ii) Administrator Information
Read DMs	(i) Promotion Information
	(ii) Administrator Information
Write DMs	(i) Promotion Information
	(ii) Administrator Information
Exit DMs	(i) Error Message
	(ii) Promotion Information

Table A.81. Measurement results of the eighth user story for third iteration

Identifier	IT3-US8		
User Story	As an employee, I want to be able to add or delete a promotion so that I can keep the list of promotions up-to-date.		
Functional Processes	IT3-US8-FP1	<i>Entry Data Movements</i>	3
		<i>Read Data Movements</i>	1
		<i>Write Data Movements</i>	3
		<i>Exit Data Movements</i>	1
		<i>Total</i>	8
	IT3-US8-FP2	<i>Entry Data Movements</i>	2
		<i>Read Data Movements</i>	2
		<i>Write Data Movements</i>	2
		<i>Exit Data Movements</i>	2
		<i>Total</i>	8
Size (CFP)			16

REFERENCES

1. Augustine, S., B. Payne, F. Sencindiver, and S. Woodcock, "Agile Project Management: Steering from the edges", *Communications of the ACM*, Vol. 48, No. 12, pp. 85-89, 2005.
2. Owen, R. L. and L. Koskela, "Agile Construction Project Management", *3rd International Built a. Human Environment Research Week*, Rotterdam, Netherlands, 2006.
3. Abrahamsson, P., O. Salo, J. Ronkainen, and J. Warsta, *Agile Software Development Methods Review and Analysis*, VTT Publications, Finland, 2002.
4. MacAulay, L. A., *Requirements Engineering*, Springer Verlag, 1996.
5. Ziv, H. and D. J. Richardson, "The Uncertainty Principle in Software Engineering", *19th International Conference on Software Engineering*, Boston, MA, USA, 1997.
6. Turk, D., R. France, and B. Rumpe, "Limitations of Agile Software Processes", *Workshops on Database Theory-XP*, 2002.
7. Boehm, B. W., *Software Engineering Economics*, Prentice Hall, New Jersey, NJ, USA, 1981.
8. Miranda, E., P. Bourque, and A. Abran, "Sizing User Stories Using Paired Comparisons", *Information and Software Technology*, Vol. 51, No. 9, pp. 1327-1337, 2009.
9. Buglione, L. and A. Abran, "Improving Estimations in Agile Projects: Issues and Avenues", *Proceedings of the 4th Software Measurement European Forum*, Rome, Italy, 2007.
10. Boehm, B. W., C. Abts, A. W. Brown, S. Chulani, B. K. Clark, E. Horowitz,

- R. Madachy, D. Reifer, and B. Steece, *Software Cost Estimation with Cocomo II*, Prentice Hall, 2000.
11. Bhattacharyya, S. P., H. Chapellat, and L. H. Keel, *Robust Control: The Parametric Approach*, Prentice Hall, 1995.
 12. Keich, U., P. Ng, “A conservative parametric approach to motif significance analysis”, *Genome Informatics*, Vol. 19, pp. 61-72, 2007.
 13. Fenton, N. E. and S. L. Pfleeger, *Software Metrics A Rigorous and Practical Approach*, PWS, 1998.
 14. *ISO/IEC 14143-1:2007-Information Technology-Software Measurement-Functional Size Measurement-Part 1: Definition of Concepts*, International Organization for Standardization, 2007.
 15. Maya, M., A. Abran, and P. Bourque, “Measuring the Size of Small Functional Enhancements to Software”, *6th International Workshop on Software Metrics*, Germany, 1996.
 16. Lambert, J. M., “A Software Sizing Model”, *Journal of Parametrics*, Vol. 6, pp. 75-87, 1986.
 17. *ISO/IEC 19761:2003-Software Engineering-COSMIC-FPP-A Functional Size Measurement Method*, International Organization for Standardization, 2003.
 18. *The COSMIC Functional Size Measurement Method Version 3.0.1 Measurement Manual*, Common Software Measurement International Consortium, 2009.
 19. Jones, C., *What are Function Points?*, 1997, <http://www.spr.com/what-are-function-points.html>, 2011.
 20. Santana, C., F. Leoneo, A. Vasconcelos, and C. Gusmao, “Using Function Points in Agile Projects”, *Proceedings of XP2011 Lecture Notes in Business Information*

Processing, Vol. 77, No. 1, pp. 176-191, 2011.

21. *International Software Benchmarking Standards Group*, 2011, <http://www.isbsg.org>, 2011.
22. Dèry, D. and A. Abran, “Investigation of the Effort Data Consistency in the ISBSG Repository”, *15th International Workshop on Software Measurement*, Montreal, Canada, 2005.
23. Highsmith, J. and A. Cockburn “Agile Software Development: The Business of Innovation”, *Computer*, Vol 34, No. 9, pp. 120-127, 2001.
24. Trudel, S. and L. Buglione. “Guideline for Sizing Agile Projects with COSMIC”, *Proceedings of the International Conference on Software Process and Product Measurement*, Stuttgart, Germany, 2010.
25. Rule, G., *Sizing User Stories with the COSMIC FSM Method*, 2010.
26. *The COSMIC Functional Size Measurement Method Version 3.0.1 Guideline for Assuring the Accuracy of Measurements Version 0.92*, Common Software Measurement International Consortium, 2011.
27. Schmietendorf, A., M. Kunz, and R. Dumke, “Effort Estimation for Agile Software Development Projects”, *Proceedings of the 5th Software Measurement European Forum*, Milan, Italy, 2008.
28. Machado, F. and L. Joyanes, “Effort Estimation in Agile Software Development”.
29. Berardi, E. and L. Santillo. “COSMIC-Based Project Management in Agile Software Development and Mapping onto Related CMMI-DEV Process Areas”, *Proceedings of the International Conference on Software Process and Product Measurement*, Stuttgart, Germany, 2010.
30. Cockburn, A. and J. Highsmith, “Agile Software Development: The People Factor”,

Computer, Vol. 34, No. 11, pp. 131-133, 2011.

31. Harris, M., D. Garmus, and M. Milutis, “The Agile Approach to Process Improvement and Its Impact on Productivity”, *Webinar*, 2007.
32. Sankaran, V., “The Agile AD Initiative at Ford”, *Agile and Beyond Conference*, Dearborn, Michigan, USA, 2011.
33. Paetsch, F., A. Eberlein, and F. Maurer, “Requirements Engineering and Agile Software Development”, *Proceedings of the Twelfth International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*, IEEE Computer Society, Washington, DC, USA, 2003.
34. *Manifesto for Agile Software Development*, 2001, <http://www.agilemanifesto.org/>, 2011.
35. Beck, K. “To Agility, and Beyond”, *Startup Lessons Learned*, San Francisco, CA, USA, 2010.
36. Bossuyt, G., *MoreAgile Manifesto*, 2010, <http://blog.xebia.com/2010/12/moreagile-manifesto>, 2011.
37. Bria, M., *Craftsmanship-The Fifth Agile Manifesto Value?*, 2008, <http://www.infoq.com/news/2008/08/manifesto-fifth-craftsmanship>, 2011.
38. *Agile Manifesto 2.0-Updates to Come?*, 2010, <http://agilescout.com/agile-manifesto-2-0-updates-to-come>, 2011.
39. Leffingwell, D. and P. Behrens, “A User Story Premier”, 2009.
40. Cohn, M., *User Stories Applied: For Agile Software Development*, Addison-Wesley, 2004.
41. Haugen, N. C., “An Empirical Study of Using Planning Poker for User Story

- Estimation”, *Proceedings of the conference on Agile 2006*, IEEE Computer Society, Washington, DC, USA, 2006.
42. *Planning Poker*, 2011, <http://www.planningpoker.com>, 2011.
 43. Host, M. and C. Wohlin, “An Experimental Study of Individual Subjective Effort Estimations and Combinations of the Estimates”, *Proceedings of the 20th International Conference on Software Engineering*, IEEE Computer Society, Washington, DC, USA, 1998.
 44. Jorgensen, M. and K. Molokken, “Combination of Software Development Effort Prediction Intervals: Why, When and How?”, *Proceedings of the 14th International Conference on Software Engineering and Knowledge Engineering*, ACM, New York, NY, USA, 2002.
 45. Bozoki, G., “An Expert Judgment Based Software Sizing Model”, *Journal of Parametrics*, Vol 13, No. 1, 1993.
 46. Miranda, E., “Improving Subjective Estimates Using Paired Comparisons”, *IEEE Software*, Vol. 18, No. 1, pp. 87-91, 2001.
 47. Shepperd, M. and M. Cartwright, “Predicting with Sparse Data”, *IEEE Transactions on Software Engineering-Special section on the seventh international software metrics symposium*, Vol. 27, No. 11, pp. 987-998, 2001.
 48. Hihn, J. and K. T. Lum, “Improving Software Size Estimates by Using Probabilistic Pairwise Comparison”, *Proceedings of the Software Metrics 10th International Symposium*, IEEE Computer Society, Washington, DC, USA, 2004.
 49. Fenton, N. E. and A. Kitchenham, “Validating Software Measures”, *Journal of Software Testing-Verification and Reliability*, Vol. 1, No. 2, pp. 27-42, 1991.
 50. Finkelstein, L., “A review of the fundamental concepts of measurement”, *Measurement*, Vol. 2, No. 1, pp. 25-34, 1984.

51. Buglione, L., “Improving Estimation by Effort Type Proportions”, *Software Measurement News*, Vol. 13, No. 1, pp. 55-64, 2008.
52. Desharnais, J. M., L. Buglione, and B. Kocatürk, “Using the COSMIC Method to Estimate Agile User Stories”, *Workshop on Managing the Client Value Creation Process in Agile Projects at Product Focused Software Development and Process Improvement*, Torre Canne, Bari, Italy, 2011.