SELECTION OF THE SOFTWARE DEVELOPMENT PROCESS MEASUREMENT COMPONENT ON SCRUM SOFTWARE DEVELOPMENT: AN ANALYTIC HIERARCHY PROCESS APPROACH

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ABSTRACT

SELECTION OF THE SOFTWARE DEVELOPMENT PROCESS MEASUREMENT COMPONENT ON SCRUM SOFTWARE DEVELOPMENT: AN ANALYTIC HIERARCHY PROCESS APPROACH

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In today's world, software evolves faster than software production can respond; therefore, software development organizations not only deal with the uncertainties inherited from requirements but also work continuously to deal with deployment issues. Scrum is the most widely known and used agile development framework that guides the development process with its ability to create customer-valued software artifacts iteratively and incrementally, while seeking best practices to provide continuous measurement during the production. However, measuring success in Scrum is a challenging endeavor. In particular, it is hard to select the best fitting agile metric during consecutive Scrum sprints. The goal of this industrial case study was to utilize a multi-criteria decision-making by using the Analytic Hierarchy Process. To this end, a systematic selection process was designed for selecting appropriate software measurement component related to the project process management with the TÜBİTAK SAGE software development group. The set of criteria, which was used for selecting the software development process measurement components, determined as relevance, experience, functionality and feasibility & usability. According to results of this study, it was determined that the criterion of relevance has the most precedence by the ratio 49.225%, this was followed by experience criterion with 22.512%, feasibility & usability criterion with 17.040%, and criterion of functionality as 11.223%. Moreover, the distribution of the process metrics preferences of the software developers was analyzed according to their characteristic features and defense industry structure by using different distribution charts. Finally, the software process measurement components, which can be easily integrated the agile software process tool that is used by TÜBİTAK SAGE software development group are determined alternatives for performing selection process with Analytic Hierarchy Process method. Among the other options, Alternative-1 was chosen as the first with 40.259%, followed by Alternative-3 with 23.632%.

Keywords: Software Measurement Component, Software Process Metrics Tool, Scrum, AHP, Software Component Selection.

ÖZ

SCRUM YÖNTEMLİ YAZILIM GELİŞTİRME KONUSUNDA YAZILIM GELİŞTİRME SÜREÇ ÖLÇÜM BİLEŞENİ SEÇİMİ: ANALİTİK HİYERARŞİ SÜRECİ YAKLAŞIMI

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Günümüz dünyasında, yazılım, yazılım geliştirmenin cevap verebileceğinden daha hızlı gelişir; bu nedenle, yazılım geliştirme organizasyonları sadece gereksinimlerden kaynaklanan belirsizliklerle baş etmekle kalmaz, aynı zamanda yazılım geliştirme sürecinin ölçülmesi ve iyileştirilmesi sorunlarıyla baş etmek için sürekli çalışırlar. Scrum, üretim sürecinde sürekli ölçüm sağlamak için en iyi uygulamaları ararken, geliştirme sürecine müşteri tarafından değer verilen yazılım ürünleri üretme kabiliyeti ile gelişim sürecini yönlendiren en yaygın ve kullanılan çevik yazılım geliştirme çerçevesidir. Ancak, Scrum'daki başarının ölçülmesi zorlu bir çabadır. Endüstriyel vaka çalışmasının amacı, Analitik Hiyerarşi Süreci kullanılarak çok ölçekli karar verme yönteminden faydalanmaktır. Bu çalışmada, TÜBİTAK SAGE yazılım geliştirme grubu ile uygun süreç metrikleri ve bu metrikleri sunan yazılım bileşeninin seçilmesi için sistematik bir seçim süreci tasarlanmıştır. Sonuç olarak, yazılım geliştirme süreç ölçüm bileşeni seçilirken kullanılan kriter seti; ilgililik, deneyim, işlevsellik ve elverişlilik ile kullanabilirlik olarak belirlenmiştir. Ilgililik kriteri %49,225 oranında önemli iken bunu %22,512 ile deneyim kriteri, %17,040 ile elverişlilik ile kullanabilirlik kriteri, %11,223 ile işlevsellik kriteri önem dereceleri olarak takip ettiği ortaya çıkmıştır. Dahası, yazılım geliştiricilerin süreç metrikleri tercihlerinin dağılımları kendi karakteristik özelleklerine ve savunma sanayinin yapısına uygun, ihtiyaçları karşılayan bulgular çeşitli dağılım grafikleri ile incelenmiştir. Son olarak, yazılım geliştirme sürecine uygun entegre edilebilir dört farklı süreç metrikleri sunan yazılım bileşeni alternatifi Analitik Hiyararşi Süreci sistemi uygulaması gerçekleştirilmiştir. Alternatifler arasında Alternatif-1 %40,259 oranı ile ilk sırada seçilirken, bu alternatifi %23,632 oranı ile Alternatif-3 izlemiştir.

Anahtar Kelimeler: Yazılım Ölçüm Bileşeni, Yazılım Süreç Metrikleri Aracı, Scrum, AHP, Yazılım Bileşeni Seçimi.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	Vise Kriterijumska Optimizacija I Kompromisno Resenje
ELECTRE	Elimination and Choice Translating Reality English
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
WIP	Work in Progress
EEE	Electrical Electronics Engineering
ME	Mechanical Engineering
CENG	Computer Engineering

CHAPTER 1

1. INTRODUCTION

Recently, the notion of quality becomes crucial for all engineering disciplines. Quality is assessed through measurements. Galileo [1] has proposed a solid argument: "*Count what is countable, measure what is measurable and what is not measurable, make measurable*". As straight logic, he claimed that everything can be quantified with the measurable forms. *What is the measurement that was mentioned by the sentence of Galileo and how does it happen?* Measurement is the process of objective association by assigning elements from number or symbol sets to the real-world properties of the entity [2]. In other words, according to Finkelstein and Leaning [3], measurement is the objective representation of the experimental knowledge of a real-world being. The measurement definition of Fenton and Bieman [4] is "*the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way so as to describe them according to clearly defined rules*.".

Measurement is a crucial part of all scientific and engineering activities. Therefore, software engineering activity is not an exception as engineering discipline. According to Pfleeger [5], software measurement will be an inseperable part of software development and maintenance. Throughout the life cycle of the software development, the measurement process should be used effectively to evaluate quality, improvement and performance of the software [6]. Today, software measurement has become a key feature to develop a successful software engineering application [7].

The software development process has a more abstract structure than other engineering activities. Software development can be considered as a social activity where software measurement can be defined as an approach used to control, manage, monitor and improve the software development process [8]. Software measurement can be divided into direct and indirect measurements. Direct measurement is the values of the internal attributes of the software such as cost, effort, speed, memory. Indirect measurement is the values of the external attributes of the software such as functionality, complexity, reliability. These measurement parameters can be used to create meaningful metrics. In this way, software metrics ecosystem can be structured to provide determination, prediction and improvement of quality of the related product or process.

Pfleeger and Fitzgerald [9] suggest that measurement data of the mid product can be used to understand the quality of the final product. In addition, measurements are known to be associated with the software development process. Thus, they are expressed that controlling activities related to process and quality of product provides evaluation of the process' maturity. Paulish and Carleton [10] introduce that software measurement with closed-loop feedback mechanism is incremental improvement for the software development processes. This is illustrated in Figure 1.

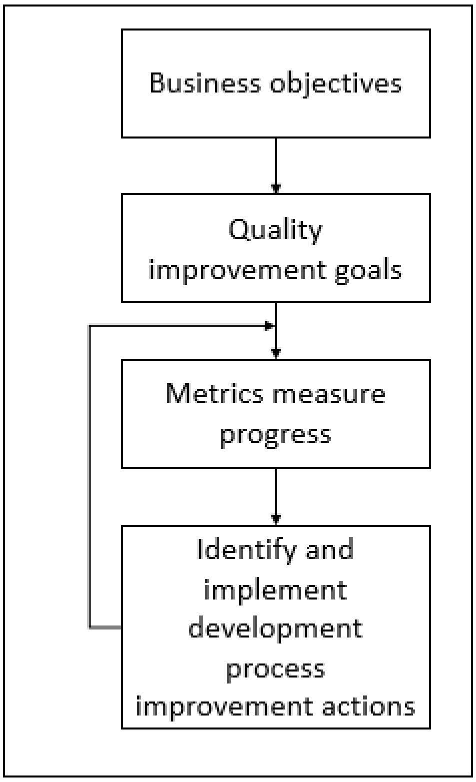

Figure 1 The approach of software measurement

The combination of the data obtained by the measurement with the useful information reveals the metric. In this way, objective measurements are converted to interpretable form. In practice, the terms of "metric" and "measure" can be utilized interchangeably. Although their definitions might have some overlapping parts, the metric is occurred by one or more measurements with the information. On the other hand, measurement is a value which is assigned to the entity [11]. However, the metrics can become more complex; as they give more information about the entity they are trying to measure [5].

The metrics in the software process similarly give valuable information about the developed product. One of the essential goals of software metrics is that it aims to eliminate human-factor uncertainties in the software measurement process. Since the collected metric data reflects the problem in the development process, the company can use these data for formulating regulatory actions and getting the software process better [10]. There are many software metrics (e.g. lines of code, code complexity, cycle time and velocity, mean time to recover) in a software development domain. In literature, there are different approaches to classify these metrics. One of them is Lee and Chang's [6] classification related to necessary metrics for software measurement with software quality. They divided software quality metrics into five groups: product quality, in-process quality, testing quality, maintenance quality, and customer satisfaction quality. Another grouping can be expressed as a commercial perspective, significance perspective, observation perspective, measurement perspective, and software development perspective. Commercial perspective includes technical metrics, defect metrics, end-user satisfaction metrics, warranty metrics and reputation metrics. Significance perspective includes core and non-core metrics. Observation perspective contains primitive and computed metrics. Measurement perspective involves direct and indirect metrics. Software development perspective includes process metrics, product metrics, test metrics, maintenance metrics and subjective metrics [7]. However, Lee and Chang [6] point out that a metric can be included by one or more categories.

Moreover, in order to exist the software process metrics, methodologies defining software development life cycle should be defined and used. Traditional methodologies are replaced by modern methodologies as the software development processes. Agile methodologies are recent methodologies that pay special attention to quality because ultimate purpose is to deliver high quality software for users. Research over the last decade shows that organizations which develop software, need to regulate agile approaches according to their requirements [12]. Scrum is one of the modern agile software development processes that is widely used and known. The most important change in the Scrum approach is the transfer of many responsibilities and decision mechanisms that were previously in administrative staff to the teams who develop software [13]. Therefore, an important purpose of Scrum metrics is to help monitoring to business development process, business quality, productivity, predictability, health situation of product and team by software team and their managers [12].

Besides the explanation above, Scrum metrics can be defined as "*focus on the predictable delivery of working software to customers*" [12]. Scrum metrics can help to observe efforts which are expended for software quality. In addition, these metrics can be used to evaluate and visualize results of these efforts. There are several defects and bugs measurements on the Scrum such as the escaped defects metric measure and how many bugs were discovered in production. Some examples of the Scrum metrics are burndown chart and team velocity [12].

Scrum methodology consists of iterative and incremental sprint structures. The target of sprint should be determined before a sprint is started [14]. Scrum metrics indicate whether or not the target of the sprint can be accomplished. Most fundamental example is that the result of sprint presents new functionality of a product. Definition of Scrum team's 'done' is that the new feature of the product is developed, tested, integrated and documantated [15]. Scrum team can monitor quantitative evaluation of the work, success rates of the sprint, maturity level of the team by using Scrum metrics [14] [15]. Sprint's success rate is an important starting point for adaptation and inspection [15]. The Scrum process evaluation metrics is shown in Table 1 [16-36].

Table 1 Scrum Evaluation Metrics

Scrum Process Evaluation Metrics	Definition
Burnup Chart	Monitor the progress of the team. The chart shows comparison between completed works and aimed finish.
Velocity Chart	The total number of values transferred in each sprint are shown in the chart. The chart allows you to guess the amount of job the team can get finished in future sprints. You can decide how much to feasibly commit with the help of chart. It can be used usefully during sprint planning meetings.
Burndown Chart	Total work progress is traced by the chart. Also, the aim sprint successful or not can be observed. By this way, the team can manage their progress and respond accordingly.
Sprint Report	The list of issues in each sprint is shown by the sprint report. Checking mid-sprint progress can be easier. Also, it can be used in the sprint retrospective meetings.
Control Chart	The cycle time or the lead time is represented for the product, version, or sprint by the control chart. Creating cycle time needs time spent by each topic in certain status. There are the average, rolling average, and standart deviation for this data in the chart.
Cumulative Flow Diagram	Stability of the flow is shown in the cumulative flow diagram. Also, focus point which makes the process more presumable can be more understandable. Quantitative and qualitative insigt into both past and existing problems can be seen easily. Huge number of the data can be visualized.
Epic Report	The list of completed, incompleted, and imponderable issues is shown by the epic report. For planning sprints, the report can be beneficial.
Epic Burndown Chart	The team's progress against the work for an epic is expressed by the epic borndown report. Huge user story that can be broken down into number of smaller stories can be defined as an epic. Data based on the estimation statistic that is utilized in the board will be expressed by the report.
Version Report	The team's progress directed the finish of a version can be shown by the verison report. Also, the predicted release data based on the team's average rate of progress can be expressed by the report.
Release Burndown	The team's progressing towards the work for a release can be shown by the release burndown report.
Feature and Epic Progress	Shows the relative progress and size of properties within a kind of project.
Multi-dimensional Backlog	Backlog of the project can be recognised comprehisibly by the multi-dimensional backlog. Also, multi-dimensional backlog tries to engage stackeholders in the bakclog.

Backlog Map	Backlog map tries to engage stakeholders in the backlog. Spent effort can be reviewed and future focus can be decided by the help of the backlog map.
Estimate Accuracy	The team's estimating performance can be seen with the estimated accuracy. In this way, the team can try to improve it.
Requirements Readiness	Focus on requirements can be improved by the requirements readiness. Distribution of sizes of work that have been done or are still in the backlog can be done with it.
Potentially Deliverable Scope	Distance to the backlog a team will get by a certain date can be shown by the potentially deliverable scope.
WIP (Work in Progress) by Team Member	The team members workloads are shown by the WIP. The WIP indicates overburdening of the members with work.
Landing Zone Story	Movements of the end dates over time can be easily shown in the landing zone chart as animation.
Time Between Events	Average spent time for combination of events can be tracked by the time between events. More details regarding WIP distribution can be understandable.
Team Status	The team member's current work and what has been completed can be tracked with the help of the team status.
Track Lead and Cycle Times	It allows to observe the lead and the cycle times. Also, it shows the task's spent times for each individual state in the workflow.
Task Status (Bird's-Eye View)	The open and complated tasks can be better viewed by the task status screen. Slicing and dicing the tasks are allowed quickly in various with the screen.

1.1. Scrum Process Metrics Add-ons

Organizations generally choose the software-based development process tools to control comprehensive system developments easily. There are various software development process tools widely used by companies to manage the Scrum process. In fact, these tools have been developed to have their own market areas that contain several add-ons. Various developers are developing adaptive applications for the software development process tools. Companies can purchase these applications for integrating them into the software development process tools as an add-on.

The variety of software process metrics is increasing day by day. Commonly used process metrics have been generally integrated into process tools as default. However, companies can expand the scope of these process metrics by purchasing extra add-ons according to their needs. The most commonly used Scrum problem & project tracking software tool contains 9 software process metrics by default. However, there are 66 metrics add-ons in its market place. Their contents, functionality and technical specifications, websites, usage training, and demonstrations are also available in the market.

1.2. The Multi-Criteria Decision-Making Methods

The selection of software metrics which is mentioned above, the choice of tools for which metrics are presented can be also very difficult and complex problem. Therefore, a systematic process is required for the selection of the metric tool kit.

Multi-criteria decision-making methods can be evaluated by taking into consideration many qualitative and quantitative criteria or purposes. Multi-criteria decision-making methods achieve the best compromise solution by examining the existing alternatives according to the determined criteria. As a result of multi-criteria decision-making methods, the decision-maker can sort, group, or make choices between existing alternatives [37]. The Analytical Hierarchy Process (AHP) approach, which is one of the multi-criteria decision-making techniques, integrates different types of criteria into a hierarchical structure and enables the evaluation of each alternative [55]. Other methods such as Electre, Promethee and TOPSIS are used to determine the weight of the criteria that affect the selection and to sort the alternatives [38]. The Analytical Network Process (ANP) defines problems, relationships between elements and directions as the form of a network. By using this structure, indirect interactions and feedbacks that are not directly related to the elements are taken into consideration [39]. If there are criteria that cannot be measured with the same scale and contradict each other, different methods are used to solve the problem. The Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method is used in this case. This method is another important multi-criteria decision-making method which is developed for optimization of the complex decision systems by using determination of the distance to ideal solution [40]. Some of the methods used for decisions making are AHP, ANP, TOPSIS, ELECTRE, PROMETHEE and VIKOR.

The aim of this study is to select the software development process measurement component which includes the appropriate software development process metrics through the AHP method. Also, software project requirements and software developers' contributions are considered as conducting a selection process.

Chapter 2 discusses the importance of selecting the right software process metrics, as well as the importance of including software practitioners or teams into the metric selection process. In addition, it presents the use of AHP, which is one of the multi-dimensional decision-making methods, in the field of software and other fields in the systematic selection process.

Chapter 3 shows the method followed in the thesis study. The characteristics of the participant groups for the case study, collection of metric suggestions from the participants, the creation of the questionnaire structure, and the identification of alternative and criterion groups are included in this part. The steps of AHP process are presented in this section.

Chapter 4 describes industrial case study results.

Chapter 5 summarizes the overall study. Then, the conclusion of the study is explained in detailed. Also, this chapter explains future studies.

CHAPTER 2

2. BACKGROUND AND RELATED WORKS

2.1. Introduction

This chapter starts with the explanation related to importance of choosing right metrics and the software process metrics, including the team in the metric selection process. Also, studies related to management of the selection process by using AHP method is explained in this chapter.

2.1.1. The Importance of Choosing Right Metrics

Pfleeger and Fitzgerald [9] conducted a detailed study about selecting the right software metrics tool kit. The researchers underlined that requirements, process, and maintainability are important factors which can be considered during the software metric selection process. Besides, they defined that customization and coordination of tool kit are as time-consuming rough activities. Card and Glass [41] stated that data collection and analysis for the calculation of metrics increased the project cost by 7% to 8% in software engineering laboratory at the University of Maryland. In another study, it was found that the collection of metrics increased the project development cost between 5% and 10% [42]. While the cost of metrics in the project and data collection are quite important, accurate data should be collected for the correct metrics. Spending time and cost with unnecessary metrics should be prevented. Researches on software measurements are continued and hot topic, today. Although the benefits of using of software measurement are known, problems in practice are still ongoing. More than 80% of software measurement attempts fail within the first 18 months [43]. The most common explanation for this problem is the difficulty in understanding and using metrics. According to Fenton and Neil [44], metrics are not used effectively in the decision-making process, because they don’t have reliability in terms of validity.

2.1.2. The Importance of Software Process Metrics

Kitchenham et al. [45] mentioned that more sensitive and considerate behavior is required in the measurement process. Ptleeger [5] has emphasized that better decisions can be made on various subjects by measuring the past and changing the future as a very strong motto. This situation involves recruitment, training and team building with the software quality. Tranter and Connors [12] have explained why the metrics are strong in agile software environment in five steps. The first is the adoption of the software metrics by the team. The metrics cannot be imposed on the team by managers. The team should be willing to understand and learn the metric. Second, the metric should start communication in the team. It's usage shouldn't a formality. Third, the metric should be used to answer a specific question about the agile processes. Fourth, a metric should not be used alone. It should be used with other metrics. Otherwise, it can focus only on one point as a tunnel vision and prevent us from seeing the big picture. Finally, the metrics should be usable, understandable and easily computable. Thus, it can take place in daily activities.

Measurement and competition are factors that encourage people to be better than the previous. For example, the progression of the runners is provided by certain measurements. Basic examples of these measurements are time-keeping and measured runways. Thus, a runner can break a record and prove with the help of measurements. Software measurements help to understand how a project performs according to its goals. Provides information about the situation of an organization compared to the previous period [8].

2.1.3. The Importance of Including the Team in the Metric Selection Process

Basically, Pfleeger and Fitzgerald [9] have explained about software metrics tool kit determination related to the needs of software development. Also, when choosing metrics for a software project development process, three concerns were taken into consideration. These were (i) the maturity of the software development process, (ii) the availability of measurement data, and (iii) the requirements of project management. For example, the researchers noticed to choose a tool kit that includes Halstead metrics when developing software that includes a database application. However, several drawbacks were revealed when the selection process of a metrics tool kit were determined by only the project managers. These disadvantages were that metric customization is time-consuming and difficult coordination of metrics usage. Paulish and Cartelon [10] suggested that an evaluation process should be realized before starting a software process improvement program. The researchers have been indicated that the evaluation is a quite powerful method that includes priorities and consensus within the organization for the improvement. According to Ebert et. al. [8], metric creators should not act independently from metrics users. They indicated that the metrics users should have advance knowledge about the software measurement process. Moreover, the users should understand how to build the measurement processes or software metrics, how to analyze the appropriate statistics and how to prove the validity of the measures or metrics. Ebert et. al. [8] have been highlighted that users of the metric should know fundamental information about the measurement process of the software.

2.1.4. AHP

Sureshchandar and Leisten [46] presented an AHP framework to priority criteria of the metrics with respect to the three categories. The objective of the study is to define the criteria and critically evaluate the metrics. They defined robustness, simplicity and cost-effectiveness as important criteria for the process metric. Ahmad and Laplante [47] have represented to introduce the application of the AHP method for selecting an appropriate software project management tool. Garg et al. [48] presented a framework for ranking of software engineering metrics based on expert opinions with the help of fuzzy-based matrix method. The aim of executing this factual research is to improve the comprehension of software engineering metrics that may have an effect on software reliability and examine the importance of their influences. Also, existing software engineering metrics have been ranked systematically according to their effects on the prediction of software reliability. Li et al. [49] proposed a meticulous application of the AHP and expert opinion for choosing software reliability metrics. Relevance, experience, correctness, practicality and feasibility were criteria that have been determined in the study. Pandey et al. [50] explained the relationship between attributes of particular metrics with empirical approaches. Choosing the significant attributes as per their weight values with the help of the AHP method to decrease the dimensionality of a metric. The cost and schedule optimization in the software development process can be reached by the dimensionality reduction. The AHP was used for continuous quality improvement program of the Latrobe Steel Company. According to the opinions of Latrobe Streel's experts [51], the AHP model was developed as a hierarchical cause-and-effect to centralize on the areas that needed to control and improve the process.

Finnie et al. [52] have been underlined several factors involved in software productivity. They identified the relationships of these factors by using the AHP technique for prioritizing these software productivity factors. Sharma et al. [53] presented the experiment that takes a real-life sample to evaluate component in terms of overall quality. The result of the study demonstrated that comparing and selecting the best suitable component can be realized with all desired quality characteristics by the AHP method. Ömürbek and Şimşek [54] determined why the online shopping site is preferred by instructors by using the AHP method. In addition, the importance of the features offered by online shopping sites has been demonstrated by using the AHP method, according to the faculty members.

In literature review phases, it has been determined that the AHP method is generally used in the selection of hardware tools such as machine equipment. Çirmen et al. [55] developed a decision support system software for the problem of machine selection using the AHP method. Qualitative criteria related to machine characteristics were determined during the selection process. In addition, the selection procedure was evaluated by sensitivity, certainty, reliability and cost analysis. Dağdeviren [56] defined an equipment selection approach in which the AHP and the Promethee methods were used together. The AHP method was used to analyze the structure of the equipment selection problem and to determine the weight of the criteria. The proposed approach was applied to the decision of an international firm's choice of a milling machine. Bazzazi et al. [40] have developed an evaluation model in the light of descriptive data for decision-making. Address the problem of selection of mine opening machine, criteria weight was determined by the AHP method and the Vikor method was applied. Pang and Chen [57] have proposed a model for the optimal design plan selection for CNC machines (Computer Numerical Control) using the AHP-based ELECTRE I method. The weights of the criteria were determined by the AHP method and design factors were listed by the ELECTRE I method. Özgen et al. [58] provided a new and effective method for machine selection problem with the fuzzy AHP-Promethee approach. The pressing machine of a company operating in Istanbul discussed as a selection problem. The results were compared with fuzzy AHP- Topsis method. Paramasivam et al. [59] used three approaches as a multi-criteria decision-making method. These are the following; directional graph and matrix approach, AHP and ANP. These three methods were applied to the grinding machine selection problem. After that, the results were analyzed and compared. Apak et al. [60] used the ANP method for the selection of luxury vehicles. Firstly, the main criteria that are important for selection were determined by taking the opinions of the vehicle sales consultants. Then, the weights of the criteria were determined by using the AHP method. The results of the study helped the consumers in the selection of luxury vehicles. Taha and Rostam [61] proposed the AHP-Promethee hybrid decision-making approach for the selection of CNC machines. In the study, the AHP method was used to determine the weight of the criteria. Kursunoglu and Onder [62] have implemented the appropriate fan selection process to be used in mine ventilation system by using the AHP method. Karim and Karmaker [63] have developed a decision support system for machine selection by the AHP and Topsis method. In this study, 7 main and 26 sub-criteria are determined, then weights of these criteria are calculated with AHP for the 3 machines in the company.

When the literature is reviewed, it has been found that there are limited number of studies using multi-criteria decision-making methodologies such as AHP method related to the selection of software metrics and their tools. Sharma et al. [64] used the Analytic Hierarchy Process (AHP) method, which is one of the multi-criteria decision-making method, for selecting software related to the project management process. The alternatives are specified as HP-PPM, Microsoft-MS-Project, and Oracle-Primavera. The criteria of the selection process are determined by reviewing literature and interviewing expert as cost, ease of use, maturity level and vendor and consultant supporting. In this study, selected criteria are assessed by interviewing with 5 project managers to select 3 project management software tools. Excel platform is used for performing the AHP process. According to the AHP selection process, HP-PPM is selected as a most appropriate software management tool. Sagar et al. [65] proposed Fuzzy-AHP method for selecting more reusable software component such as plug-ins. They determined criteria that points reusability as adaptability, availability, interface complexity, customizability and understandability by reviewing related literature. In addition, 6 software component alternatives are specified. Java programming language is used for implementing Fuzzy-AHP process. As a result, AVG- antivirus software component is selected most reusable component. In the studies of Ömürbek et al. [66] it was aimed to select project management program which can be used in software development by using AHP and TOPSIS method. In this study, it has been tried to determine with which institutional project management program the software development processes carried out within the Computer Center of a university by using the AHP method. In this context, 4 programs were evaluated according to 13 different criteria. Expert opinions and classifications in the literature have been utilized in the determination of the criteria for evaluation. These criteria are supplier firm and purchasing, ease of use, adaptation and technical infrastructure and support. Within the framework of these criteria; Atlassian-Jira, HP-PPM, IBM-Rational Request and Microsoft-TFS alternative tools have been evaluated. The weights of the criteria using the AHP method were determined in the Microsoft Excel program. In the paper of Al-Qutaish et al. [67], the Analytical Hierarchy Process (AHP) method was used for managing the selection process of open source software according to the ISO 9126-1standard related to six quality characteristics. These are: functionality, reliability (R), usability, efficiency, maintainability, portability. They specified 5 different open source software as alternatives. According to the study, it was determined that OSS 4 is the first ranking alternative based on the quality characteristics. Zaidan et al. [68] presented open-source electronic medical record software packages selection approach based on AHP and TOPSIS method. The technical details, usability, functionality and features, security, user support, developer support, customizability, ease of installation are determined as criteria for selection the process after literature reviewing phase of the study. Results of the study showed that GNUmed and OpenEMR software have high ranking score when compared to other open-source EMR software packages.

In literature review phases, the importance of software process metrics in improving software quality was realized. In addition, the cost of unnecessary metrics usage was emphasized. Moreover, it was stated that users should be included in the metric selection. However, the software development process metrics are presented as generic structure by the software process tracking tool. Also, there are several metric add-ons that have been seen offer the Scrum process metrics as sub-groups kit products. It is a difficult and complex issue to decide which add-ons to use because it is known that this process is affected by multi-criteria such as the type of software developed, the development process model, the experience of the software developers, the domain of projects and the duration of the project. Therefore, there is a need for a systematic selection process for the solution of this multi-criteria problem.

In this study, in the light of the information which is mentioned above, the selection of the add-ons which include the software process metrics was performed with the AHP method. The purpose of this study is to examine the selection of the components that offer the software development process metrics with the AHP method which is one of the multi-criteria decision-making methods. In this context, the weighting of selection criteria and the evaluation of alternatives were carried out for selecting add-ons that include the software process metrics as an industrial case study in the TUBITAK SAGE software development group.

2.1.5. Summary

When the literature is examined, it is realized that the importance of metric selection process clearly. In the literature, the advantages of including the team to the metric selection decision-making process are mentioned. Because the selection of process metrics components is a difficult and complex problem, a systematic decision-making process is needed to manage this process. It is observed that the use and success of the AHP method are evident capabilities of this method, which is commonly known from multi-criteria decision-making methods. Therefore, it is decided to use the AHP method as a systematic decision-making process.In the following chapter, the followed method is explained. The method part includes obtaining the ideas of a study group and evaluating and analizing them by using expert opinions.

CHAPTER 3

3. METHODOLOGY

3.1. Introduction

This section describes the methodology of the current study. This section starts by presenting and explaining the steps to be followed. Next, some explanations related to the process metrics collections steps, and the information in terms of the process metrics of the Scrum methodology are given. Also, the details of the study group and the expert group are mentioned in this part. Then, the process of applying the metric selection survey is explained. Finally, the structure, steps, application, and formulas of the AHP method are examined in detail.

First of all, the appropriate software development process measurement component selection problem was determined. Then, the survey was implemented on the study group. After that, the AHP method was implemented by the contribution of the expert group. The priorities of criteria and alternatives were evaluated. Finally, the highest priority alternative was selected as a final decision. Figure 2 presents all steps of the case study process.

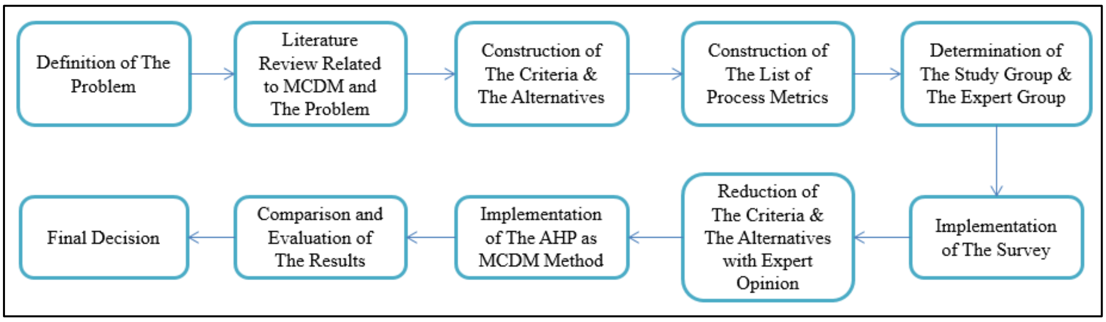

Figure 2 Steps of the case study process

3.2. Collection of Process Metrics

A suggestion is defined as the psychological process to guide through of people [69]. It is a set of selected or prioritized opinions that a person shares on a particular topic. Proponents, who favor a particular idea, should usually consist of experienced people.

Suggestions can be listed to present simple and primitive form. In addition, several graphs are used for better understanding of survey results. Besides, suggestions have been associated with categorical information such as years of experience, departments, and graduation departments to represent frequencies and varieties of them.

3.2.1. Scrum methodology process metrics

List of the software process metrics that are appropriate to the Scrum software development process is constructed by:

- The tool of the Scrum issue & project tracking software which has 9 software process metrics as default.
- There are various Scrum process metrics that can be integrated into the tool of the Scrum issue & project tracking software by providers of an add-on.
- Users can customize the Scrum process metrics with the help of several add-ons.

The software development process metrics for the Scrum methodology are shown in Table 1 in the introduction part.

3.2.2. Identification of the study group and the expert group

3.2.2.1. Study group

The study group consists of project software developers who can take responsibility as a developer in the software department during the software development process. This group has been selected, because they recognize the corporate culture, realize the software development process, are aware of the things they are doing well or the problems and have their strong experience in software development domain.

3.2.2.2. Expert group

The expert group consists of employees who have at least 5 years of experience in software development. The group members have titles such as the team leader, unit manager, coordinator and/or chief scientist. Also, this group has the primary responsibility to make decisions about the software development process.

3.2.3. Implementation of the survey

A software development process meeting was organized in the unit where the study will be carried out. The participants were informed about the process metrics survey. The participants of the meeting were the study group and the expert group. The study group and the expert group were asked to review the list of software development process metrics and to report their preferences through the survey (see Appendix A). Customized process metrics can be suggested in the survey that was indicated at the first meeting with the study group. In addition, the announcement was that information about the years of work experience, experience domains, graduation departments, and the working units will be collected from the participants with the survey.

The survey was prepared on the Google forms for using survey templates to create a survey. Additionally, data which is collected from Google forms, can be converted into the graphical format. The Scrum software development process metrics in Table ***1*** is presented as options. Participants were informed about the meanings, visual graphs, usage purposes and usage areas of these options through the website before joining the survey in order to better understand the options [16-36]. The survey schedule was announced to participants one week in advance. On the last day of the expiry date, a reminder was made by using the intranet.

The survey results were grouped and associated with the personal information which was collected from the participants. The findings obtained from the survey were presented graphically to the expert group. Analytical processable format of the collected data is converted graphical form as pie charts and bar graph by using Google Sheets and Microsoft Excel. It is aimed that the expert group will be influenced by pie charts and histograms determining the criteria related to the AHP method and in evaluating the alternatives. Reduction of the criteria and the alternatives were conducted according to the results of the survey by the expert group.

3.3. Determination of the Criteria & the Alternatives

When determining the software development process metric add-ons, it was taken into consideration that they can be integrated to the Scrum software development process tool used at the company to be carried out the industrial case study. The market of the tool of Scrum issue & project tracking software was examined then, the list was determined 66 products as add-ons applications. 66 products of:

- Technical specifications and capabilities (types and number of process metrics)
- Usage rate in the market
- The scoring rate in the market

were examined. While some of these were primitive and specific products that only offered a few metrics, some of them were observed to submit a comprehensive process metrics service. Considering the suggestions of the developers, it has emerged that an advanced add-on product including metrics other than 9 core process metrics should be preferred.

The alternatives of add-on products can be compared with each other, and their functionalities should highly provide for the requirements of software developers process metrics. Alternatives:

- Having technical specifications to meet the needs
- Be accessible and available
- Having visualization and/or report mechanism

are required.

The literature includes several criteria for metric tools. It is observed that software process metrics tools aim to increase market sales by highlighting these criteria. It has been determined that important criteria are emphasized in the technical documents of metric tools. These criteria are listed in Table 2.

While evaluating the software process metrics, robustness, simplicity and cost-effectiveness are pointed as key parameters [46]. This is because, processes have been defined with systematic and powerful procedures. The processes have been described quite simply. Finally, it has been emphasized that the processes should be cost-effective. The following criterion group can be used when evaluating tools that offer the software development process metrics [49,53]:

Table 2 Software process metrics add-ons evaluation criteria

Criteria	Meaning
Relevance	(to collected process metrics) This criterion reflects the relationship between process metrics and the metric tool.
Experience	Degree of the metric tool which has been used and recognized is reflected by this criterion.
Correctness	This criterion includes objectivity, justness and precision. According to the objectivity, the input and results of this process metric tool can't be easily influenced. According to the justness, any specific result should not be part of the metric tool. According to the precision, the metric tool has to measure precisely.
Practicality	The metric tool should be required and concerned in development and improvement.
Feasibility & Usability	Three conditions should be considered for investigating the criteria. These are that understandability of all formulas in the metric tool should be high, data collection should be easily, and convenient evaluation of the result of the metric should be realized.
Functionality	The criterion reflects that the metric tool should provide technical requirements: high number of the essential process metrics, advanced level of the strength of visualization and reporting mechanism.

Adaptability & Portability	The criterion reflects that the metric tool can be integrated to the process methodology, portable and have easy and less time of integration with the software development process management tool.

The expert group performed the reduction process by considering the results of the survey. After that, the set of criteria and the set of alternatives in the AHP method have become the final version.

In the study, reliability of the reduction operation is implemented by using Cronbach's alpha method. Cronbach's alpha have been used for estimating a measure of the internal consistency of an assessment [70]. It is represented by numbers between 0 and 1 in terms of reliability scale [71]. The internal consistency scale are classified as follows at Figure 3:

Cronbach's alpha	Internal consistency
$0.9 \leq \alpha$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Figure 3 Internal Consistency Scale of The Cronbach's Alpha

Cronbach's alpha is formulated as:

$$\propto = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \propto_{Y_i}^2}{\propto_X^2}\right), \tag{2.1}$$

Where K is the number of items, $\propto_X^2$ is the variance of total items, and $\propto_{Y_i}^2$ is the variance of item i.

If only 0 and 1 are used as items' score, the formula is formed as:

$$\propto = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} P_i Q_i}{\propto_X^2}\right), \tag{2.2}$$

Where P_i is the ratio of scoring 1, and Q_i is calculated with P_i which is substructed from 1 [72].

The formula is named Kuder-Richardson Formula 20 (KR-20). It is a special case of Cronbach's alpha formula with dichotomous selections.

Determining internal consistency should be performed to ensure validity of an assessment. Furthermore, the reliability estimates demonstrate the failure rate (error variance) of an assessment [70]. The failure rate is determined by squaring the internal consistency value and subtracting from 1.

$$Error\ Variance = 1 - \propto^2 , \tag{2.3}$$

Where α is the reliability value of the Cronbach's alpha.

3.4. Multi-Criteria Decision-Making Method

Decision-making is a phenomenon which occurs every time of life. Generally, decision-making is assessment the process of most appropriate one or more alternatives which depend on a metric and oriented at least one purpose inside alternatives cluster. This process includes decision-maker, alternatives, criteria, environmental factors, needs of decision-maker and results of decision. Decision-making process can be ended with selection, ordering or classification between existing alternatives. In this, situation, multi-criteria decision-making method is occurred for making correct decision [73] [74]. Multi-criteria decision-making (MCDM) is a decision process which allows to use at least two criteria inside cluster occurred by countable finite or uncountable number of alternatives [75].

3.4.1. AHP Method

The Analytical Hierarchy Process (AHP) is a method based on basic math and psychology which is found by Thomas L. Saaty in 1980 for use to solve complex problems. It is one of the multi-criteria decision-making methods that can be used to solve economic, social and technical problems [76]. AHP is an intuitive and logical scrutinized approach at decision problems between elements which have complicated relationships inside. Also, it provides a simplified way for hierarchical structure [77]. This hierarchical structure depends on that inferior criteria effect senior criteria. Therefore, the degree of the effects between criteria should be determined [78].

3.4.1.1. AHP Method Steps

The steps of AHP methods are occurred by beloved steps [79] [80].

Step 1: Definition of decision problem

The first step is that decision making problem should be expressed clearly. The problem should be determined for appropriate or not to AHP by consequences of literature researches, experiences and expert's opinions. After determining appropriation of problem to AHP, problem can be divided into sub-problems. Then, sub-problems can be solved so that a general solution can be obtained [81].

Step 2: Creation of hierarchy structure

Hierarchy is represented by at least three levels at AHP. Purpose is at the top level of hierarchy. There are main criteria in a lower level of the top level. If any, inferior criteria are demonstrated under main criteria. At the bottom level, there are alternatives [81] [82]. Three level hierarchical structure is shown at Figure 4.

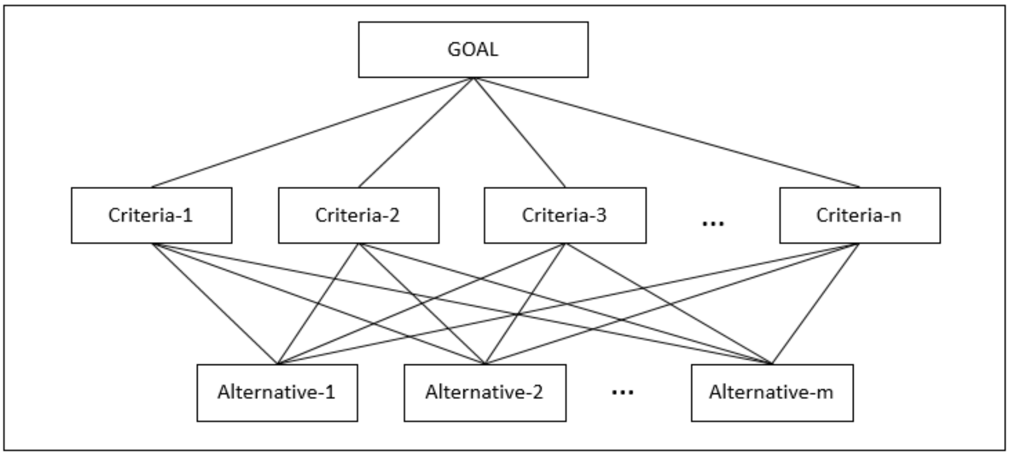

Figure 4 AHP hierarchy structure

Step 3: Forming the matrices of pairwise comparison of criteria

Matrices of pairwise comparison is a significant step for AHP after creating hierarchical structure. Score scale should be used which is proposed at Figure 5 by Saaty when these matrices are forming [76].

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one over another
5	Strong importance	Experience and judgement strongly favour one over another
7	Very strong importance	An activity is strongly favoured, and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero numbers		if activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

Figure 5 Saaty Importance Scale

Figure 5 Saaty's scale of measurement in pair-wise comparison

Criteria should be compared between each other to determine the degree of importance of the criteria to be used for comparing alternatives. Comparison should be done by experts. According to the scoring scale given in Figure 5, comparison matrices are formed as in Table 3 by making pairwise comparison between criteria [83]. The formula of

$$a_{ij} = 1/a_{ji} \text{ ,} \tag{2.4}$$

where

$$a_{ij} \in \text{Comparison Matrix} \tag{2.5}$$

should be used for remainings under diagonal. Element of the comparison matrix is shown a_{ij}. To give an example, if a_{13} value is 5, then with using equation of a_{31}=1/ $a_{31,}$ a_{31} value should be found 1/5 = 0.2.

Table 3 Comparison matrix

A	Alternative 1	Alternative 2	Alternative 3	…	Alternative n
Alternative 1	1	a_{12}	a_{13}	…	a_{1n}
Alternative 2	a_{21}=1/ a_{12}	1	a_{23}	…	a_{2n}
Alternative 3	a_{31}=1/ a_{31}	a_{32}=1/ a_{23}	1	…	a_{3n}
…	….	…	…	1	…
Alternative n	a_{n1}=1/ a_{1n}	a_{n2}=1/ a_{2n}	a_{n3}=1/ a_{3n}	…	1

Step 4: Calculation of priority vector (W)

After forming the matrix of pairwise comparison, priority vector which shows the priority of each element in matrix relative the other elements should be calculated.

In order to normalize matrix of pairwise comparison, each element is divided by summation of its column. The formula can be expressed as

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, \tag{2.6}$$

where a_{ij} is from equation (2.5).

End of the process, sumation of each column should be equal to 1 in normalized matrix. After that, each summation of row value should be divided by number of rows to calculate aritmetic mean. Formula can be expressed as

$$w_i = \frac{\sum_{i=1}^{n} b_{ij}}{n}. \tag{2.7}$$

where b_{ij} is from equation (2.6).

Percentage of importance level of criteria can be presented by

$$W=[w_i]_{nx1} \tag{2.8}$$

where w_i is from equation (2.7).

vector in result of this process [81].

Step 5: Calculation of λ_{max} and consistency index (CI)

Consistency index should be calculated by decision-maker for finding that is matrices of pairwise comparison which is formed by values determined by comparison between criteria consistent or not. λ_{max} should be canculated for consistency index. Formula of λ_{max} can be expressed as [80]

$$D= [a_{ij}]_{nxn} \text{ x } [w_i]_{n\,x1} =[d_i]_{nx1}\,, \tag{2.9}$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \frac{di}{wi}}{n}, \tag{2.10}$$

where d_i is from equation (2.9), w_i is from equation (2.7).

Consistency index can be calculated with

$$\text{CI} = \frac{\lambda max - n}{n-1}. \tag{2.11}$$

where λ_{max} is from equation (2.7).

Step 6: Calculation consistency rate (CR)

Value of random consistency index (RI) is needed for calculating consistency rate. RI values which is occurred by constant values and according to n value are shared at Table 4 [80].

Table 4 Random consistency index

n	2	3	4	5	6	7	8	9	10
RI	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Consistency rate can be found by using folowing equation [81].

$$CR = CI/RI \tag{2.12}$$

where CI is from equation (2.11), RI is from Table 4.

If

$$CR \geq 0.10\ , \tag{2.13}$$

where CR is from equation (2.12),

decision-maker should revise its decision. In this situation, matrix of pairwise comparison should be arranged again [81].

Else if

$$CR < 0.10\ , \tag{2.14}$$

where CR is from equation (2.13),

consistencty rate is provided.

Platform: Super Decisions software version 2.10.0 was used to implement the AHP method in this study. The software provides to calculate weights and compare pairwise alternatives and criteria [84].

3.5. Conclusion

The information related to the process metrics is collected by the survey method from software developers. It is provided that all information were gathered without being affected by each other and their preferences were grouped. The structure of the study and the expert group is defined. In the next chapter, the results of the industrial case study are shown. The results can be accessed by applying the steps in chapter 3 and visualized by graphs for better understanding. The findings are presented along with the comments of the graphical results.

CHAPTER 4

4. RESULTS AND FINDINGS

4.1. Introduction

In this thesis, an industrial case study is conducted and the results of the previous chapters are given in this chapter. A graphical presentation is made for a better understanding of the experimental results. During the analysis of the results, it is considered that the characteristics of the group that evaluated and the requirements of the projects they carried out.

4.2. Study Group

The study group consists of 28 software developers. The distribution of the study group according to the graduation department is given in Figure 6.

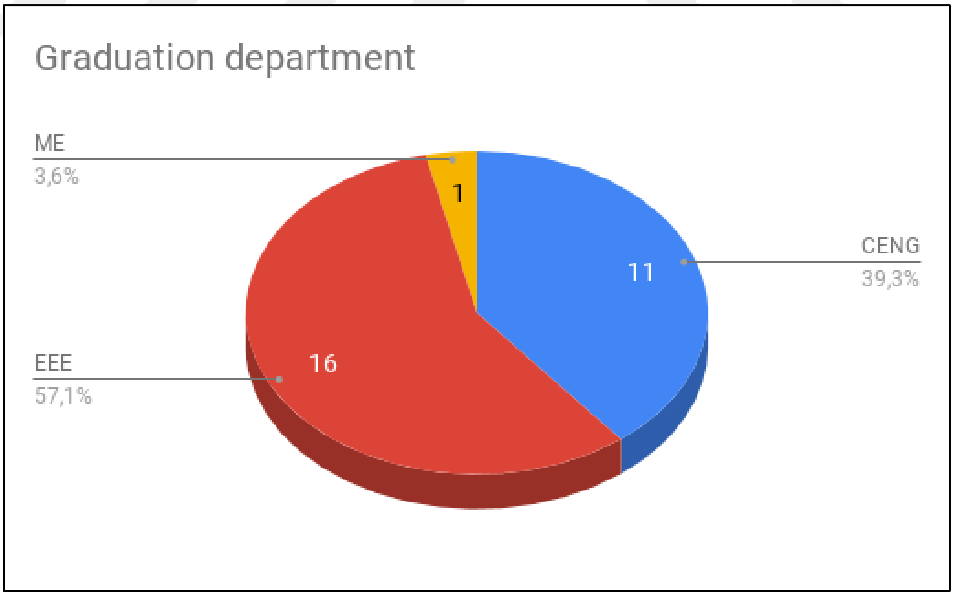

Figure 6 The graduation department of study group

Figure 6 shows that the study group is consist of 16 electrical electronics engineers that are graduated from electrical electronics engineering (EEE) department, 11 computer enginners that are graduated from computer engineering (CENG) department and a mechanical engineer that is graduated from mechanical engineering (ME) department. The majority of the study group is composed of electrical electronics engineers. The reason is that before the software development group was created, this group members were also working in the electronic design unit of the company. Moreover, electrical electronics engineers were generally preferred since embedded software work was done for the software development group.

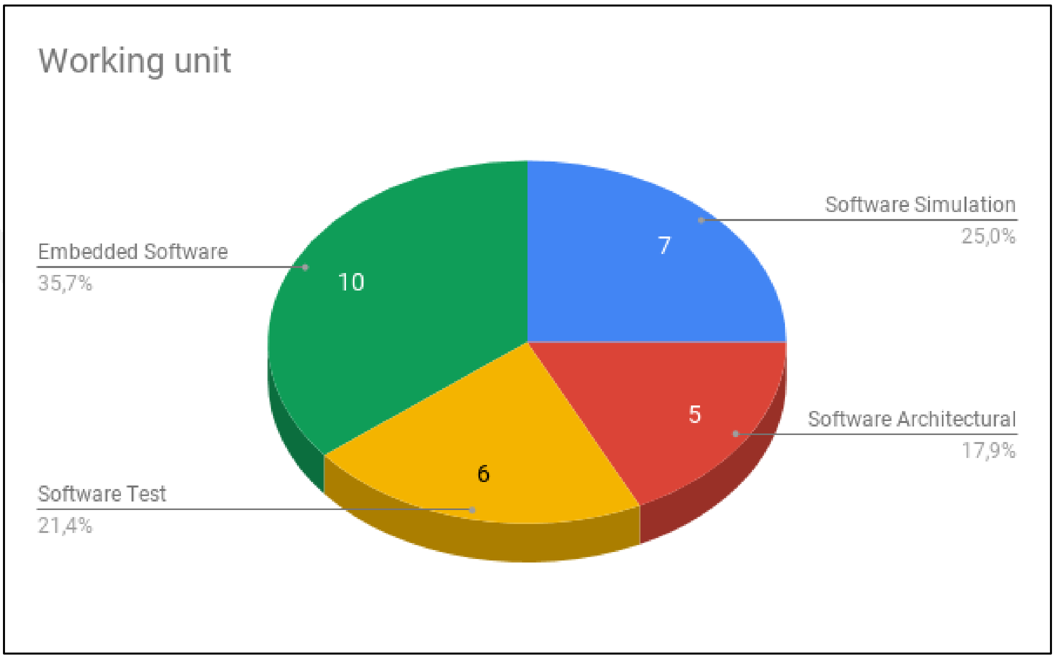

Figure 7 The working unit of study group

Figure 7 shows that the working unit of study group. The study group members work in four different units: embedded software, software simulation, software test and software architectural design. There are most 35.7% embedded software developers and least 17.9% software architectural design developer in the study group.

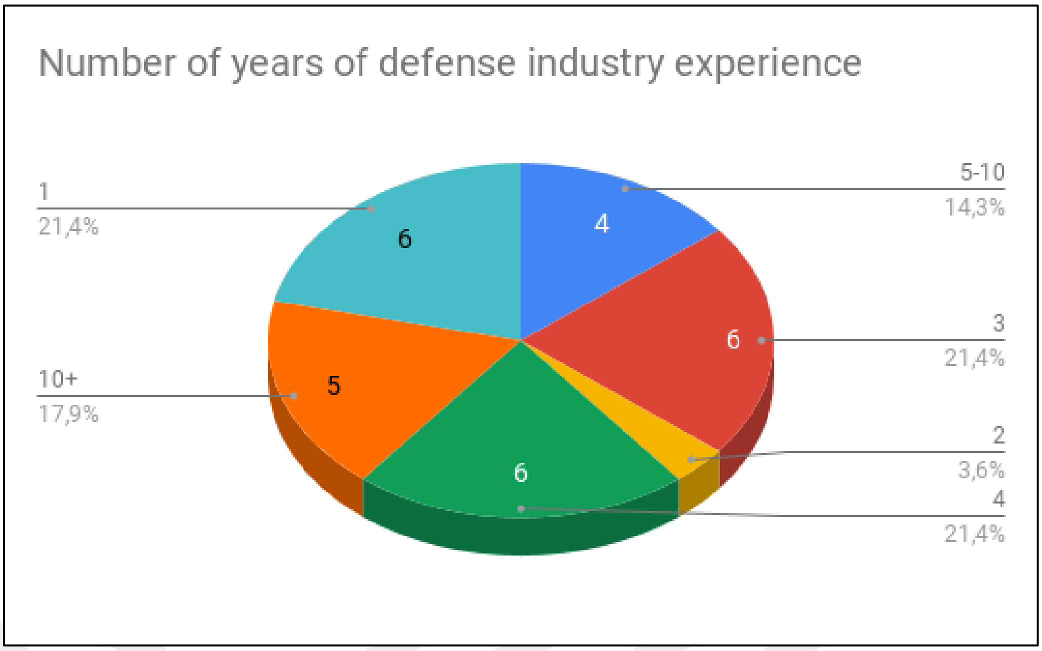

Figure 8 The defense industry experience years of study group

Figure 8 represents the experience years in defense industry of the study group. According to this figüre 53.6% of the study group members have 4 years or more experience while 46.4% of the study group members have less than 4 years experience. Moreover, 57.1% of these members have no experience in different sectors in Figure 9. In addition, it is determined that 17.9% of the proportion of the study group have only one year experince.

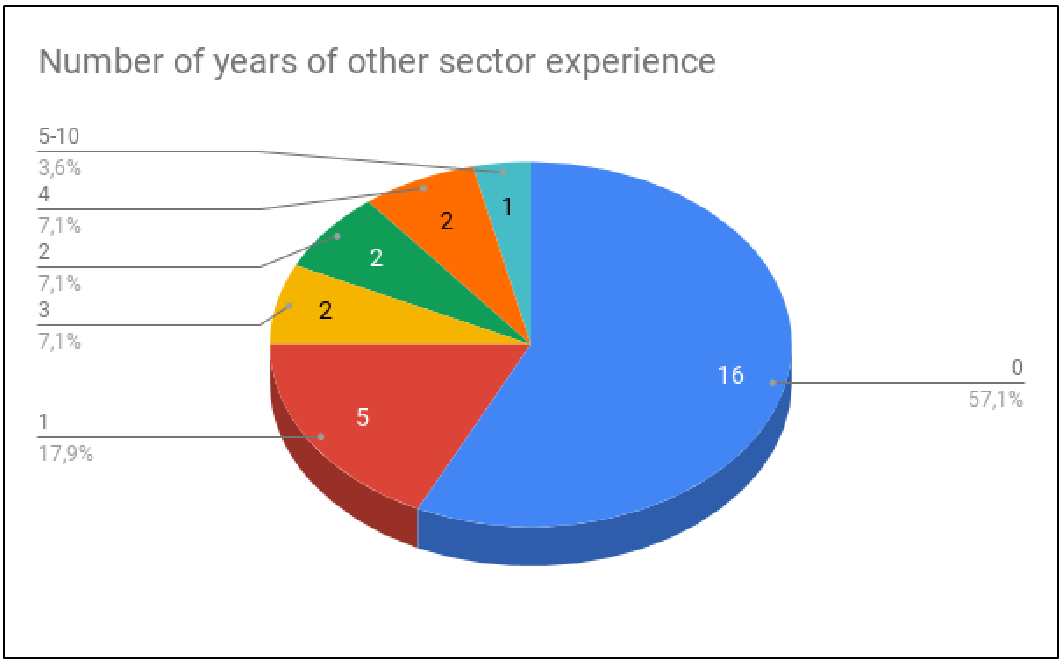

Figure 9 The other sector experience years of study group

4.3. Results of Collection of Process Metrics

After the completion of the survey (shown in part A of appendices), the process metrics preferences of the study group have been transformed into various graphics in order to better understand the results. 8 pie charts and 1 horizontal bar chart show the distribution and density of the options.

Figure 10 represents the frequency at which each option is selected.

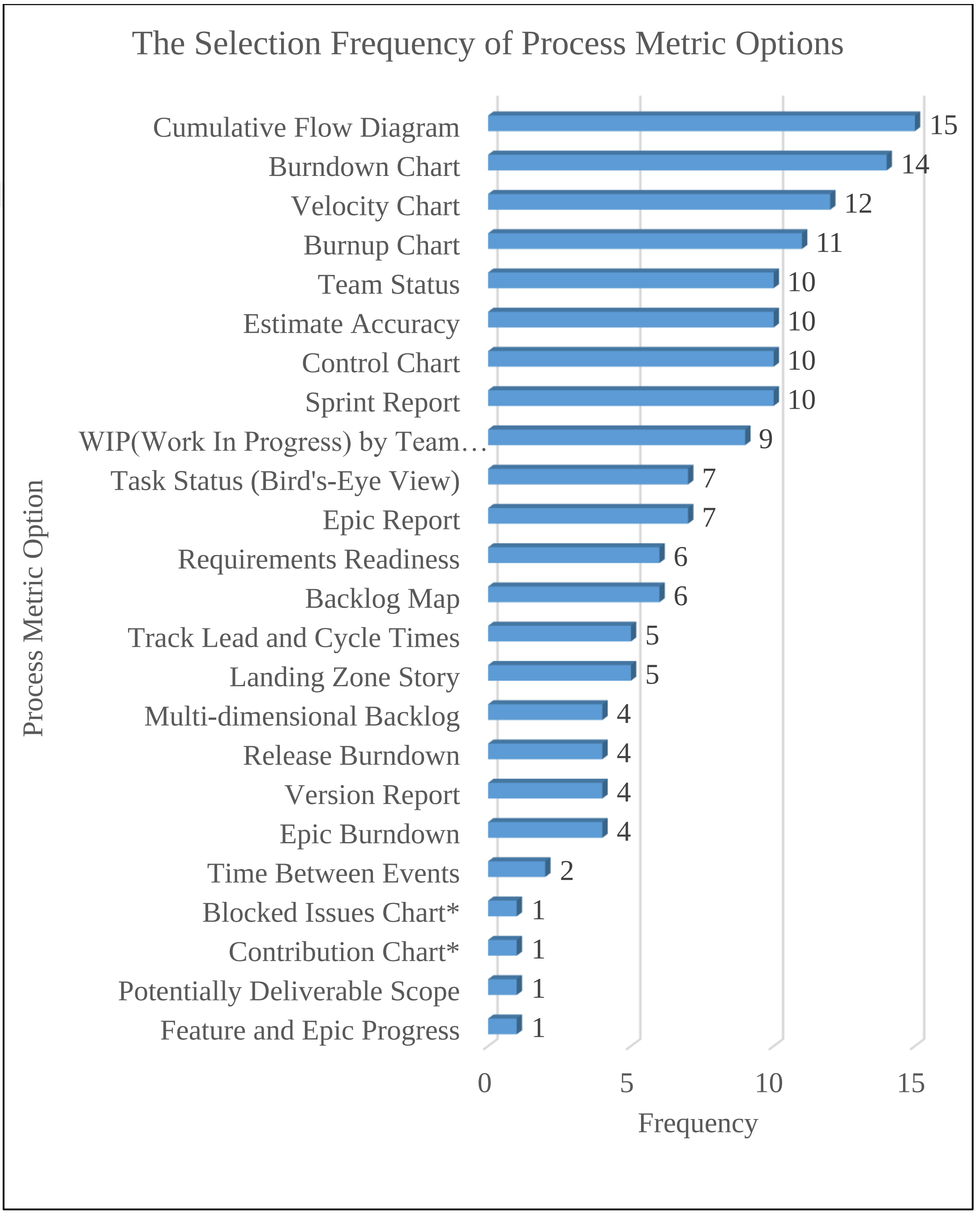

Figure 10 The selection frequency of process metrics

Cumulative flow diagram was the most selected software development process metric by 15 participants of the study group members. Burndown chart, velocity char and burnup chart were the selected options for more than 10 participants. The blocked issues chart and the contribution chart were marked with the symbol '*' because they are other options added by the participants. Potentially deliverable scope and feature and epic progress have been preferred by only one participant. Most of the software development process measurement components have been observed to contain cumulative flow diagram and burndown chart. In other words, the majör part of the selections of the study group can be covered by the software development process metric providers.

All pie charts legends are listed from the least selected option to the most selected option. Looking at the colors with this order is the right method.

Figure 11 illustrates the distribution of the preferences of 53.6% of the study group that had defense industry experience of 4 years and more. A cumulative flow diagram is the highest selected process metric. Feature and epic progress, potentially deliverable scope, and time between events are the lowest selected process metrics. Moreover, it was determined that the priority of the participants in the status of the projects in the process. Because highly selected options have the ability to monitor the completion of the software development process. Their primary concern can be the status of the process.

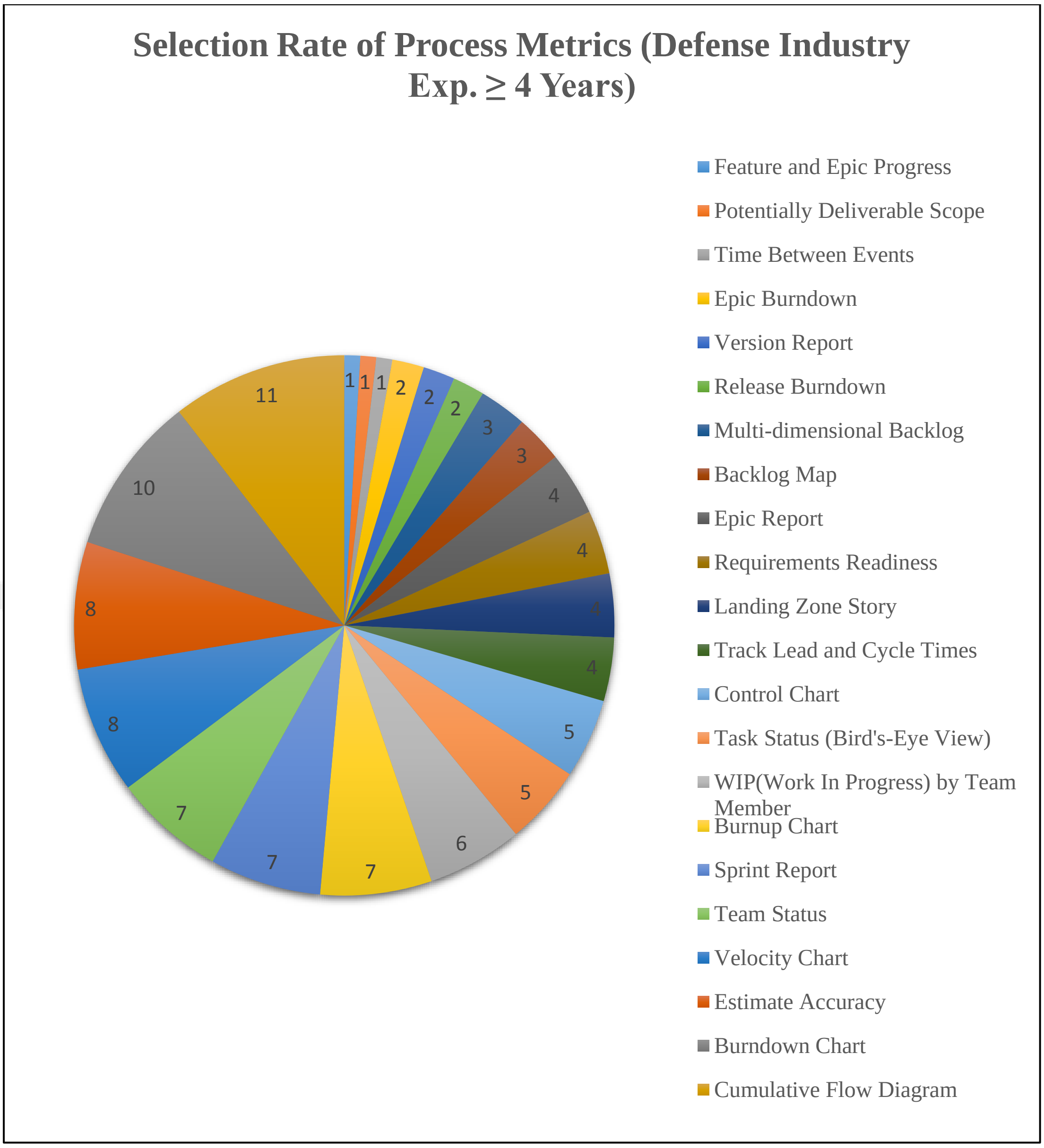

Figure 11 The selection rate for more than four years of experience

Figure 12 shows the choices of the less than 4 years defense industry experienced study group. The control chart is the most selected process metric. The control chart helps determine future performance status. Therefore, the fact that it is selected by less experienced study group members indicates that they care about performance development.

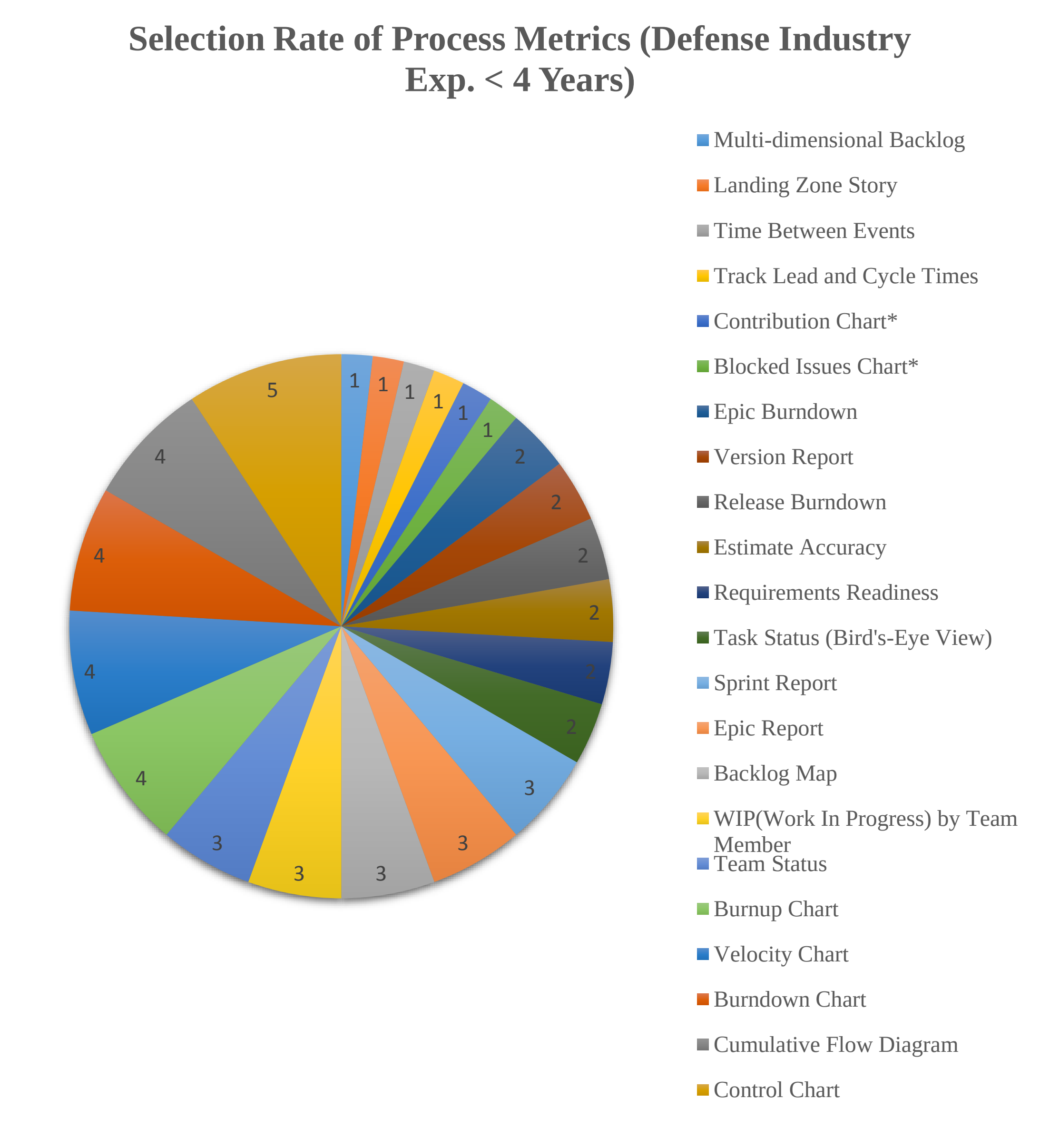

Figure 12 The selection rate for less than four years of experience

Figure 13 represents the distribution of the preferences of computer engineers in the study group. Cumulative flow diagram is the most preferred process metric. 7 different process metrics are selected once which are epic report, multi-dimensional backlog, WIP by team member, time between events, track lead and cycle times, contributin chart and blocked issues chart. Since computer engineers have learned the theoretical aspects of the software development process metrics in the academic environment, they can offer different suggestions. On the other hand, it is understood from the readiness requirements selection that they give importance to the determination phase of the requirements. Also, they prepared the requirement document in their academic processes. For this reason, 'requirement readiness' is one of the priorities.

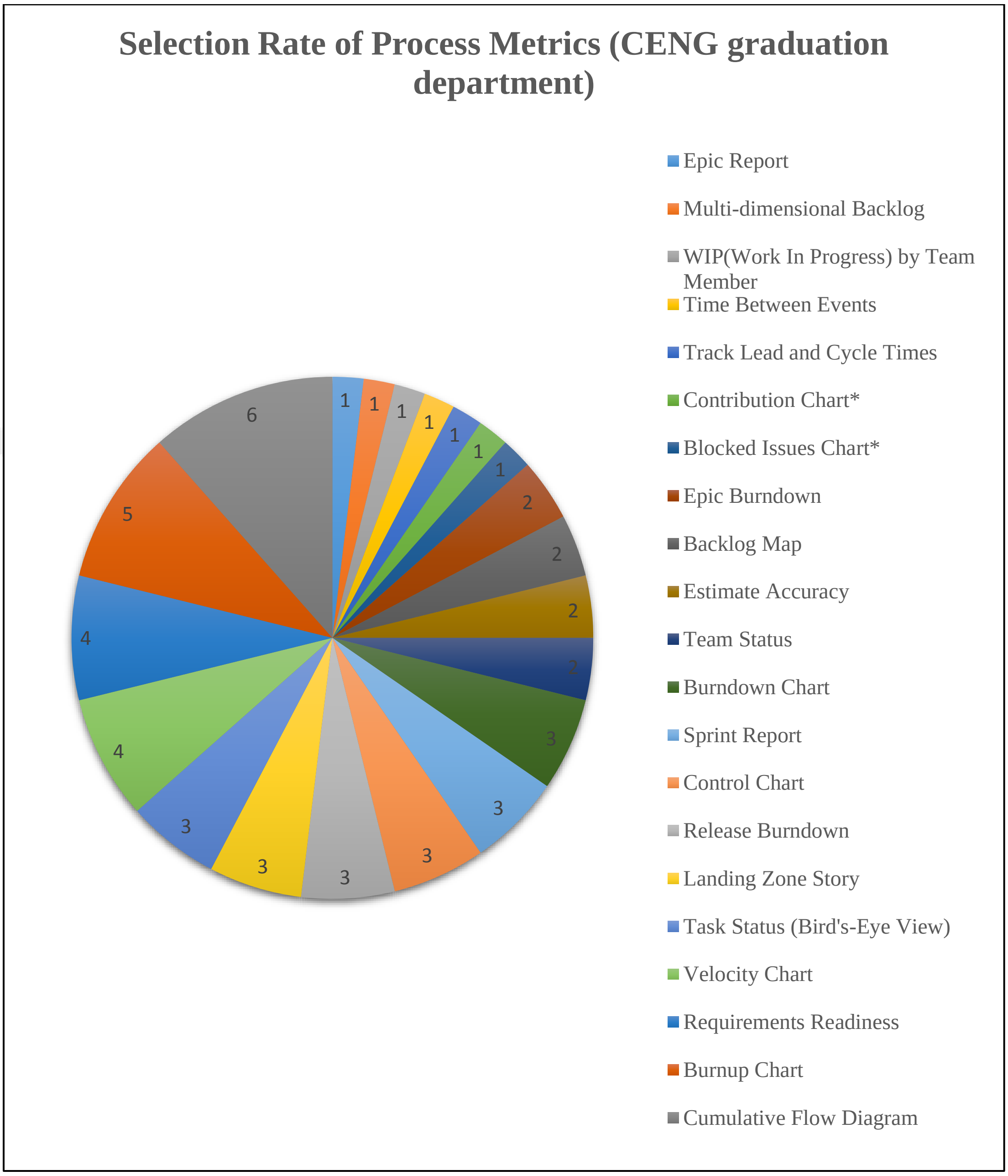

Figure 13 The selection rate of computer engineers

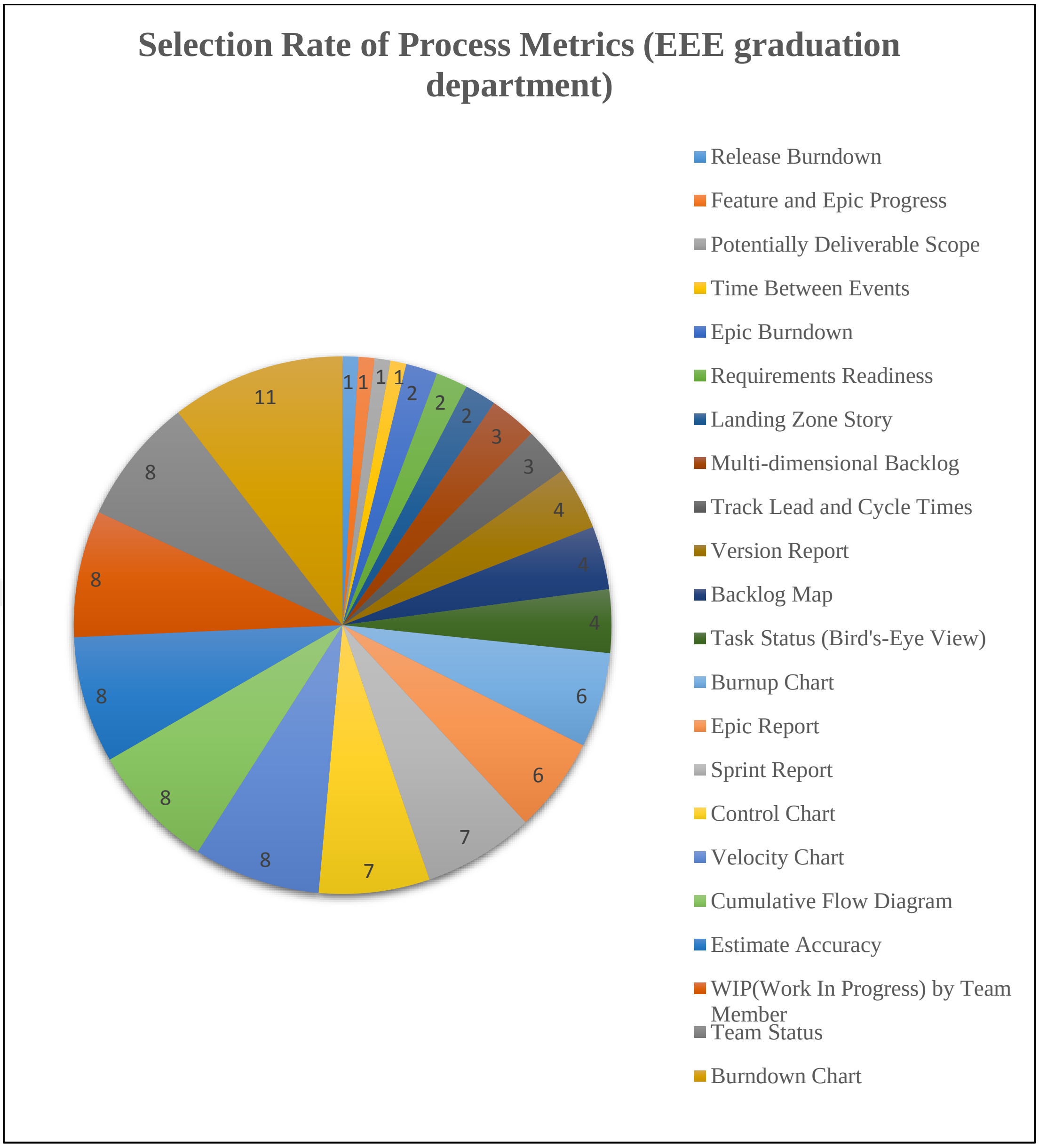

Figure 14 The selection rate of electrical & electronics engineers

Figure 14 shows the distribution of electrical electronics engineers' selections in the study group. While the burndown chart was the most selected process metric, 4 different process metrics have been chosen only once. These are release burndown, feature and epic proress, potentially deliverable scope and time between events. The embedded software unit includes more electrical and electronics engineers. They have selected team status and WIP by team member metric, because more their workloads can be observable.

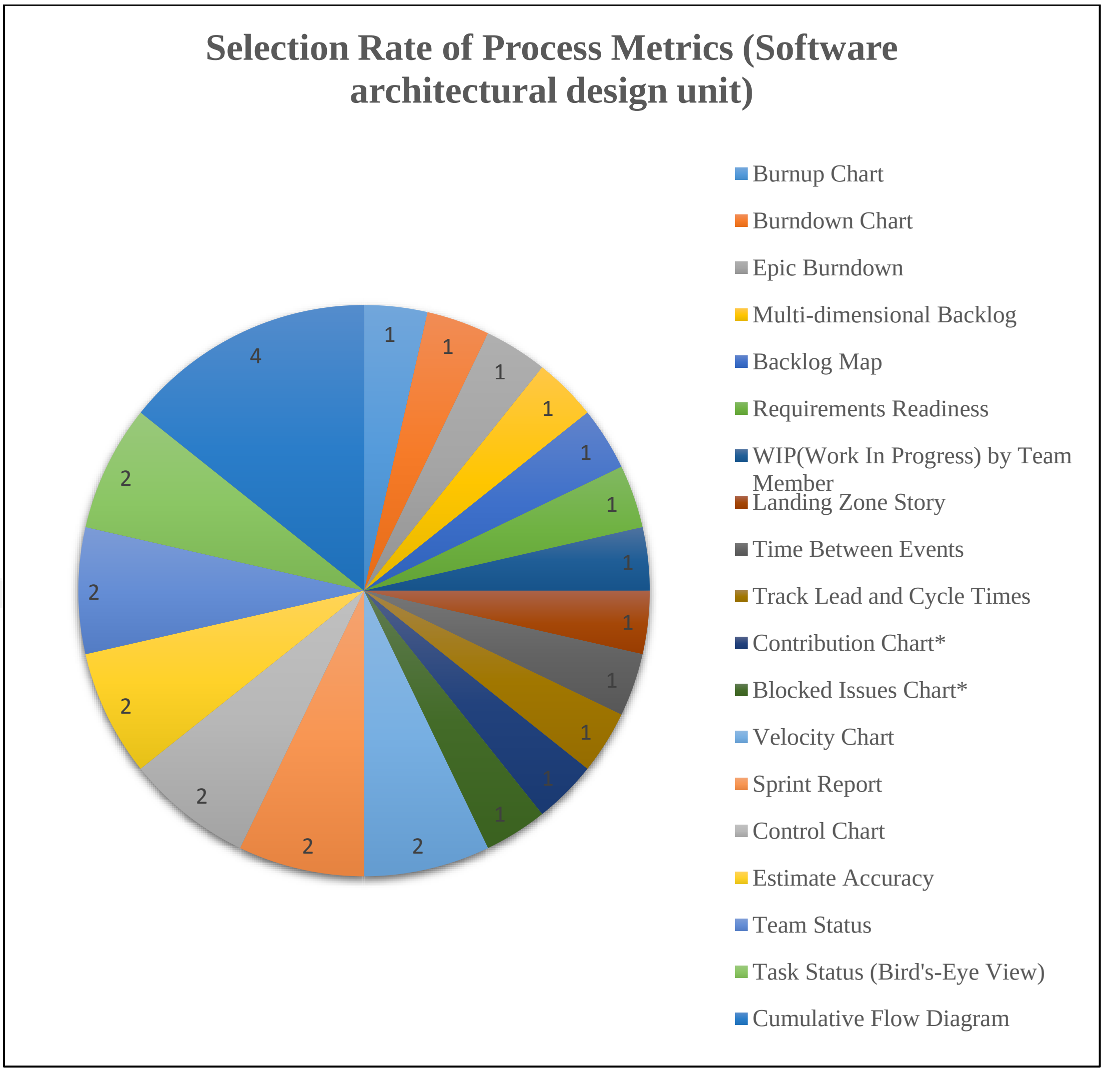

Figure 15 The selection rate of software architects

Figure 15 represents the preferences of software architects. Cumulative flow diagram was the most selected process metric. 12 process metrics were selected once. The process metrics preferences of software architects are focused on observing the process.

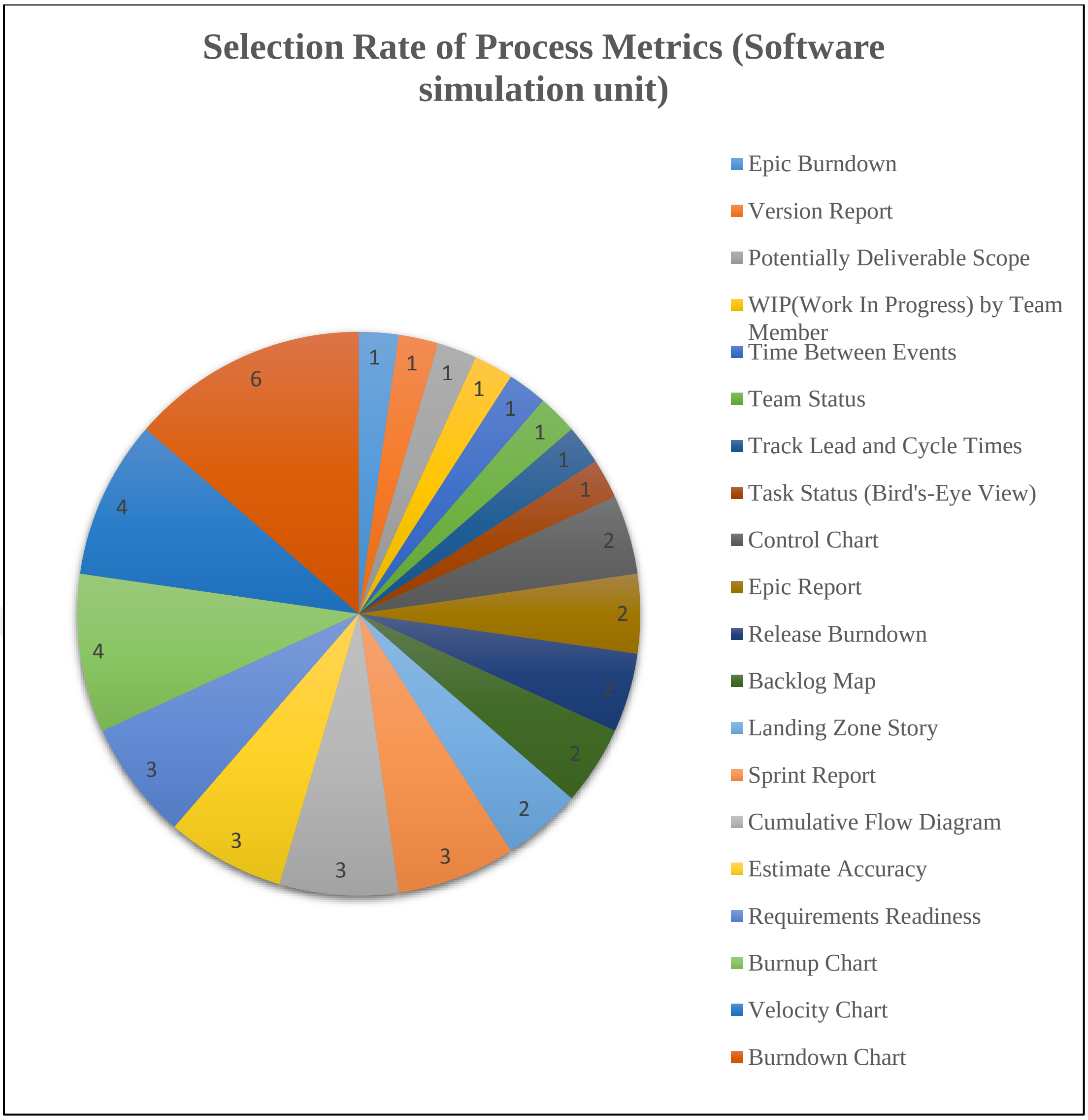

Figure 16 The selection rate of software simulation unit's workers

Figure 16 shows software simulation unit workers preferences. The burndown chart was the most preferred process metric. 8 process metrics were preferred once. These are epic burndown, version report, potentially deliverable scope, WIP by team members, time between events, team status and track lead and cycle times. The participants who work at the software simulation unit generally preferred graphical speed and the process flow metrics that have intense visualization.

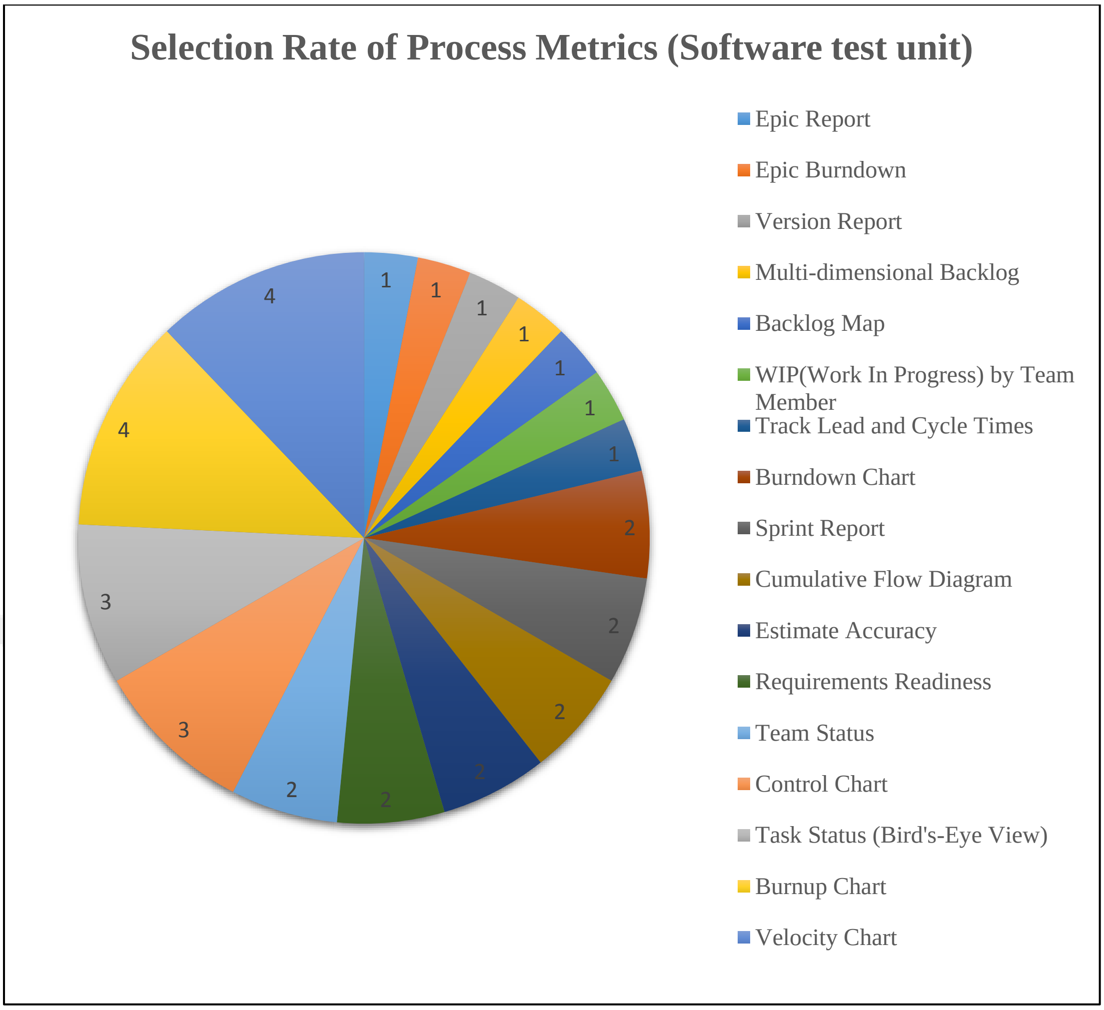

Figure 17 The selection rate of software test unit's workers

Figure 17 shows the software test unit workers preferences. Velocity chart and burnup chart is the most preferred process metric. 7 process metrics were preferred once which are epic report, epic burndown, version report, multi-dimensional backlog, backlog map, WIP by team member and track lead and cycle times. At the end of the process, tested works are deployed. It was thought that, the software testers may try to eliminate the workload by paying attention to the work speed at the end of the process.

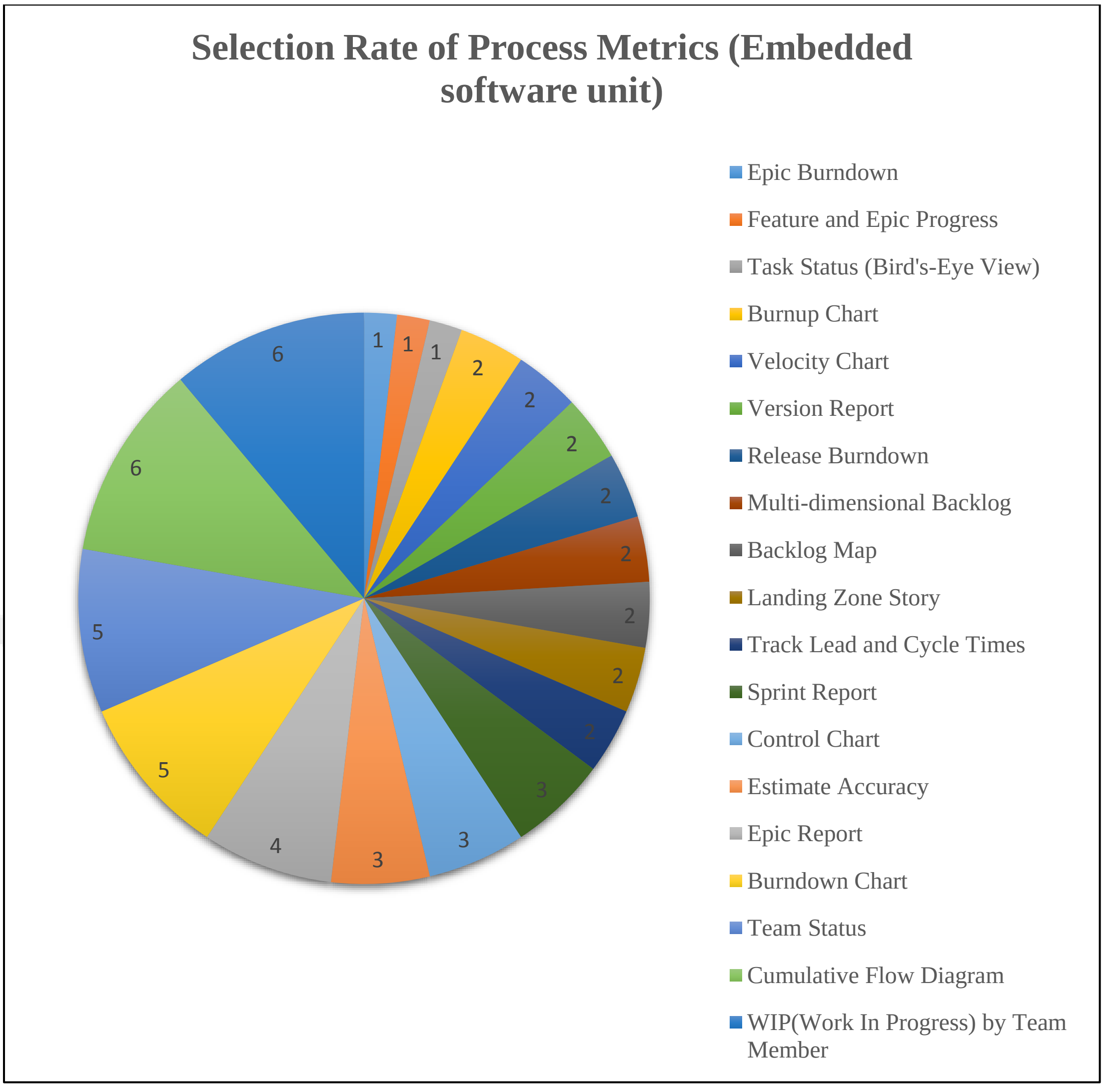

Figure 18 The selection rate of embedded software developers

Figure 18 shows the preferences of embedded software developers. WIP was the most preferred process metric. The embedded software developers have completed many issues through the software development process cycle. Therefore, they may choice WIP which represents the workload to reflects their working status in software unit. In addition, 3 process metrics were preferred once. These; epic burndown, feature and epic progress and task status.

4.4. Expert Group

Table 5 Expert Group Information

Experts	Year of experience	Roles and Responsibilities
Expert 1	16	Coordinator
Expert 2	6	Project Team Leader
Expert 3	19	Software Test Unit Chief
Expert 4	13	Software Simulation and Mission Planning Unit Chief
Expert 5	13	Embedded System Unit Chief
Expert 6	15	Software Architecture Design Unit Chief

The expert group includes software development group coordinator, 4 unit chiefs of software development units and one project team leader that are presented in Table 5.

4.5. Determination of Alternatives

The add-on products that can be integrated into the software development process management tool used by the TÜBİTAK SAGE software development group have been evaluated. It is known that, the global marketplace of the tool includes 66 add-on products for software process metrics. Some of these are primitive and specific products that offer only a few metric, while some offer a comprehensive process metrics service. Currently used tool in software department provides 9 common process metrics. Considering the suggestions of the study group, it has been understood that the tool contains insufficient process metrics. Moreover, it is seen that advanced add-on products that offer preferred process metrics should be selected. As a result, user reviews in the market, user ratings, and software development experts' opinions have been identified alternatives as 4 add-on products. The alternatives were determined by the feedbacks of expert group. Table 6 represents the alternatives of software development process metrics add-on product.

Table 6 The list of add-on product alternatives

The Add-on Product Alternatives
Alternative 1
Alternative 2
Alternative 3
Alternative 4

4.6. Determination of Criteria

After determining the add-on product alternatives, the criteria were determined by the expert group. For this step, the studies which are about selection of the software metrics component in the literature, were examined. After that, the expert group considered the results graphs of the survey (horizontal bar chart and 8 pie charts) of the study group.

4.7. Reduction of the Criteria

At this state, the criteria in the literature were explained to the expert group. Figure 9-17 are shown to the expert group. The expert group recommended criteria that should be looked at different times and places. Table 7 represents the criteria preferred by the expert group.

Table 7 Selected criteria of expert group

Expert Group	Selected Criteria
Expert 1	Relevance Experience Correctness Practicality Feasibility & Usability Functionality Adaptability & Portability

Expert 2	Relevance Experience Feasibility & Usability Functionality
Expert 3	Relevance Experience Correctness Practicality Feasibility & Usability Functionality Adaptability & Portability
Expert 4	Relevance Experience Practicality Feasibility & Usability Functionality Adaptability & Portability
Expert 5	Relevance Experience Practicality Feasibility & Usability Functionality
Expert 6	Feasibility & Usability Functionality

Table 8 shows the frequencies of the criterion selected by the expert group. The criteria selected by the entire expert group and the criteria selected by at least 5 are shown in green. Others are shown in red. The criteria group was formed with criteria of green color.

Table 8 Selection frequency of the criteria

Criteria	Selection Frequency
Relevance	**5**
Experience	**5**
Correctness	**2**

Practicality	**4**
Feasibility & Usability	**6**
Functionality	**6**
Adaptability & Portability	**3**

As a result of the consolidation of these two evaluations, reduction of the criteria is completed. The criterion group was formed by the expert group. The criteria set out in Table 9 are shown.

Table 9 Determined criteria

The Criteria
Relevance
Experience
Feasibility & Usability
Functionality

After the evaluation process of the criteria was performed by the expert group, Cronbach's alpha value was calculated with the results of the evaluation. MedCalc which is the statistical calculation software was used to measure the internal consistency of the results [85]. The value of an internal consistency was obtained as 0.805. The mean of the value represents 'Good' according to Figure 3 scale. Also, the error variance of the evaluation results was calculated as 0.351. According to Cronbach's alpha and error variance which is obtained by performing different calculation, the evaluation process of the study particularly, reduction operation has been satisfied reliability consideration. Therefore, proposed selection method can be generalized other problem domains in a confidential way.

4.8. Solution of the Problem

The hierarchical structure has been established between the criteria and the alternatives. Figure 19 shows the AHP hierarchy structure of the software development process measurement component selection.

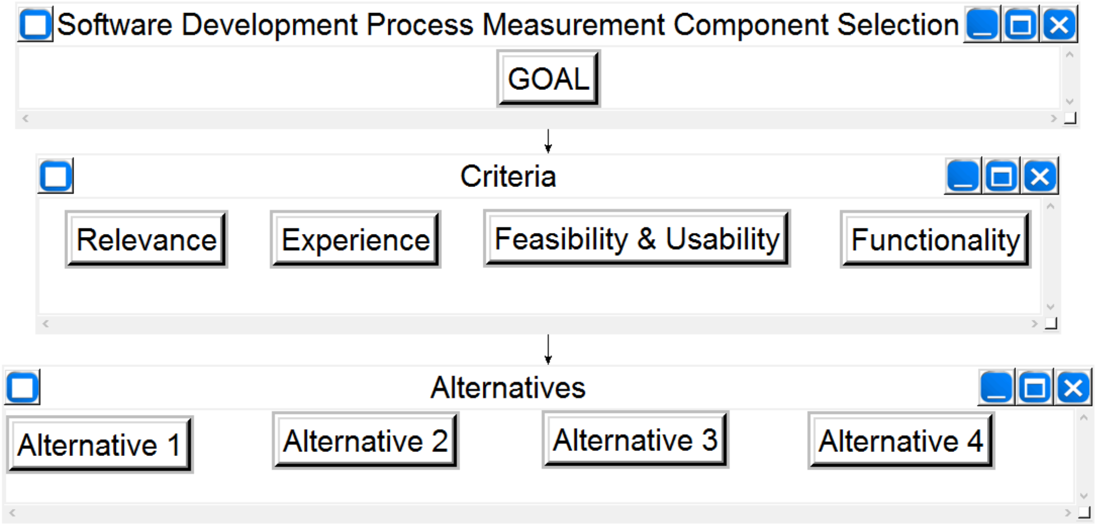

Figure 19 The AHP hierarchy structure of the component selection

Figure 19 shows the hierarchical structure of the criteria and alternatives which are determined for the software development process metric add-ons selection problem.

4.9. Weighting Criteria

Pairwise comparison was provided to the expert group for weighting the criteria (see Appendix B).

Figure 20 shows the weights of the criteria related to Expert 1. Relevance has the highest weight with a value of 0.675. Functionality has the lowest weight with a value of 0.025.

Figure 20 The weights of criteria by Expert 1

Figure 21 shows the weights of the criteria related to Expert 2. Relevance has the highest weight with a value of 0.694. Feasibility & Usability has the lowest weight with a value of 0.048.

Figure 21 The weights of criteria by Expert 2

Figure 22 shows the weights of the criteria related to Expert 3. Relevance has the highest weight with a value of 0.593. Functionality has the lowest weight with a value of 0.054.

Figure 22 The weights of criteria by Expert 3

Figure 23 shows the weights of the criteria related to Expert 4. Experience and Relevance have the highest weight with a value of 0.431. Functionality has the lowest weight with a value of 0.032.

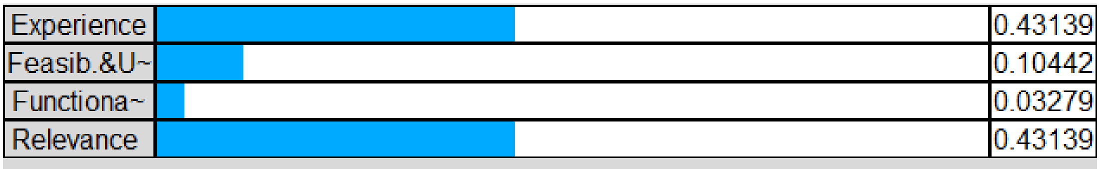

Figure 23 The weights of criteria by Expert 4

Figure 24 shows the weights of the criteria related to Expert 5. Relevance has the highest weight with a value of 0.498. Functionality and Feasibility & Usability has the lowest weight with a value of 0.086.

Figure 24 The weights of criteria by Expert 5

Figure 25 shows the weights of the criteria related to Expert 6. Functionality has the highest weight with a value of 0.392. Revelance has the lowest weight with a value of 0.060.

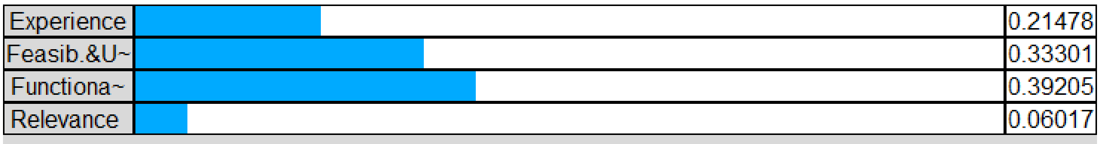

Figure 25 The weights of criteria by Expert 6

When the mean of the values in Figure 19-24 are taken, the values in Figure 26 are obtained.

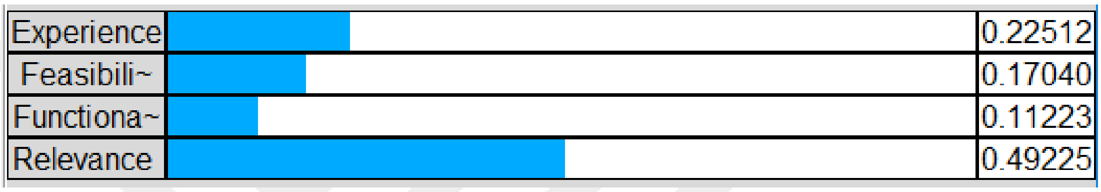

Figure 26 The mean of criteria weights

The decision matrix was created by using the Super Decisions program. As a result of the matrix, weights of the criteria were obtained. Figure 26 shows that the screenshot of the Super Decisions program, which includes priorities for the criteria set for the process metric add-ons selection problem. According to Figure 26, the relevance criterion has the maximum weighy 0.492. The experience criterionis followed by the 0.225.

4.10. Evaluation of Alternatives

Before evaluating the alternatives by the expert group, important information about alternatives were supplied to the expert group which are given below:

- Definitions of criteria as Table 2
- Saaty scale and its meanings as Figure 5
- Links of alternatives in market areas. There are user comments, user reviews, user ratings in these web sites.

- Links of technical documents of alternatives. They provide comprehensive information on the technical specifications of the alternatives.
- Links of the alternative as a web-based demo which are provide opportunitiy to use alternative by sample data.
- Links of the alternative usage as a video demonstration.

All links which are mentioned above, pairwise comparisons of alternatives and table can be handle were send as an document to Expert group by an e-mail. Also, expert group were returned within a week.

Evaluation results of the alternatives are presented in Table 10-15 for each expert.

Table 10 Priorities of the alternatives by expert 1

Alternatives	Normalized
Alternative 1	0.496525
Alternative 2	0.131850
Alternative 3	0.131850
Alternative 4	0.239775

Table 11 Priorities of the alternatives by expert 2

Alternatives	Normalized
Alternative 1	0.158578
Alternative 2	0.264367
Alternative 3	0.514031
Alternative 4	0.063024

Table 12 Priorities of the alternatives by expert 3

Alternatives	Normalized
Alternative 1	0.245287
Alternative 2	0.199712
Alternative 3	0.340189
Alternative 4	0.214811

Table 13 Priorities of the alternatives by expert 4

Alternatives	Normalized
Alternative 1	0.609958
Alternative 2	0.044955
Alternative 3	0.249409
Alternative 4	0.095678

Table 14 Priorities of the alternatives by expert 5

Alternatives	Normalized
Alternative 1	0.340028
Alternative 2	0.259949
Alternative 3	0.087146
Alternative 4	0.312878

Table 15 Priorities of the alternatives by expert 6

Alternatives	Normalized
Alternative 1	0.565216
Alternative 2	0.227213
Alternative 3	0.095336
Alternative 4	0.112234

Priorities of the alternatives is calculated by using means of the Table 10-15. The results are given in Table 16.

Table 16 Mean Priorities of the alternatives

Priorities of The Alternatives	**Normalized Values**
Alternative 1	0.402598667
Alternative 2	0.188007667
Alternative 3	0.236326833
Alternative 4	0.173066667

The decision matrix was created by using the Super Decisions program. As a result of the matrix, weights of alternatives were obtained (see Appendix B). In Table 16 as seen in the normalized analysis results, the Alternative-1 has the maximum weight (0.402). The Alternative-3 is in the second order with the normalize value (0.236).

4.11. Discussion of the Results

While selecting generally the project management tools in the literature, the plug-in was selected as a software component to make strong the process management tool in this study. The AHP approach was also applicable in this study as well as studies of Sureshchandar and Leisten [46], Sharma et al. [64], Sagar et al. [65], Ömürbek et al. [66] and Al-Qutaish et al. [67]. In this study, the criterion of usability was determined as ease of use criterion that was determined in the study of Sharma et al. [64]. The experience criterion was used in this study likely understandability criterion at the study of Sagar et al. [65] and maturity level criterion at the study of Sharma et al. [64]. The functionality criterion was determined by the expert group such as technical infrastructure criterion from the study of Ömürbek et al. [66] and functionality criterion from works of Al-Qutaish et al. [67] and Zaidan et al. [68]. Unlike these studies, it is thought that high priority prioritization of relavence criterion affects study group cooperation. In contrast to the other studies, the contribution of the study group was highlighted in the evaluation of the criterion pool expert group.

In this study, the software development process metrics that are preferred by the software development group of the institution contributing to the defense industry were reflected. Preferred metrics are considered to be suitable for the characteristic structures of the study groups and the company. Moreover, highly selected metrics such as cumulative flow diagram, burndown chart are commonly provided by all software process measurement components. In other words, the study group may not be considered to be in contradictory selections. When evaluating the criteria by the expert group, it can be considered that the study group's preferences were taken into consideration. The reason for this is that the relevance criterion has a significant value. It can be possible to say that the expert group has been given sufficient time for the evaluation process to create healthier results. On the contrary, it is thought to reflect objective evaluations.

4.12. Threats to Validity

Yilmaz [86] describes the "threats to validity" as one of the leading factors that can decrease usefulness, trust-ability and correctness of the study. The following methods which are used for mitigating threats to validity are discussed under the following sub-titles as internal validiy, external validity and construct validity.

Internal Validity:

- It has been provided that the expert group has properly completed this process in terms of validity the enough time and place are given to them to handle selection.
- In order to prevent the participants of the study group from being influenced by each other during the interpretation of the survey results, interviews is conducted with each of them in separate environments.
- During the study process, measurement instrument is not changed.

External Validity:

- During the study process, participants and study setting such as software unit are not changed in any way. The study group which are determined initial phase of the experiment, is kept same in all steps of the process.
- Only professional software developers is selected as the study group. In addition, those who have at least one year of professional experience in this group is included in the study.
- This study is carried out by using survey which has multiple answering options. Metric preferences are not only performed with multiple choice options. The study group is able to make suggestions through open-ended part of the survey.
- The AHP approach is not applied on only one expert. When the opinions of six different experts are collected, also the criteria in the literature are evaluated and determined.
- The selection of criteria based on majority is carried out. With the evaluation of criteria and alternatives to the whole members of expert group, reliability has been increased. In other words, the same method has been applied to more than one expert. A more reliable result is obtained by taking the mean of the results.

Construct Validity:

- Qualitatively, it is checked that the evaluation of the researcher and the study participants whether they have similar interpretation on the survey results.
- Quantitatively, it is checked that the internal consistency of an assessment by using Cronbach's alpha for measuring reliability of the criteria reduction operation.

CHAPTER 5

5. CONCLUSION AND FUTURE WORK

In this study, a systematic process was followed for the selecting software development process measurement component which is a complex problem. In this context, in the selection of software development process metrics; a selection approach, in which the software team is included in the selection process and collaborates with the team, is proposed, in accordance with the characteristic structure and requirements of the company, projects and team. The systematic process was followed to make a more objective and accurate decision. Thus, the most suitable software development process measurement component selection was performed.

In this study, decision-makers are included in the systematic decision-making process. In the industrial case study carried out by the AHP method, the relevance criterion was determined as the highest priority criterion of the software team. It was thought that the study group members' considering that the institution, projects and software development team have proposed the metrics that are suitable for the characteristic structures as the cause for this situation. Thus, the decision-making expert group examined the graphical results of the collected process metrics. Here, it can be said that expert group members are affected by accordance to the need for relevance. In addition, it can be said that information such as comments, scores and use percentages of previously experienced people may have come to the attention as the reason for giving second priority to experience criterion. In addition, it has been determined that study group members give almost equal priority to functionality and feasibility & usability criteria. Expert-4, one of those who consider the functionality criterion to be a low priority, has verbally stated: It is more important to usage proportion of the features than the high functionality of the vehicle. An example of this is that some of the tools owned by the organization have been upgraded with 100 new features, but this new feature is not being used and the basic functions are being continued.

It was also determined that alternative-1 was prioritized at the highest level with 40.259% as a result of the systemic process in the evaluation of alternatives. It was observed that the expert group had difficulty in discrete thinking at the beginning of the evaluation process. Once this problem has been identified, it has been determined that the expert group has successfully completed this process when the appropriate time and place are considered for them to think. The evaluation process of the expert group was shaped by considering that human perception may initially have difficulty in focusing on discrete evaluation and discrete criteria. In the alternative evaluation process, alternatives are usually reviewed and dominant alternative are determined by one or more reasons. Here, it is thought that the expert group evaluates the pool of criteria in their perceptions in a holistic way, or that the focus on a single alternative for a particular reason is broken. For this reason, a selection process was conducted by considering the problems and requirements of the study group during the implementation process.

The case study has proven that multi-criteria decision-making process and in particular, the AHP method can be used effectively for selecting software metric component in the software domain. In the future, it is considered that this study may serve as an example for the AHP method to be preferred when systematic decision-making is needed in the field of software. In addition, it is thought that the contribution of the software development group to the decision-making process will support the use of the selected metric components in a positive way. Using appropriate software development components increases the ability of companies to compete in the future. Finally, this study can be performed using the fuzzy AHP method. Moreover, the ANP and TOPSIS method can be used together with the AHP method as a hybrid method to perform in the study.

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Part I

Appendix A

Appendices

The Survey of Software Development Process Metrics

Software Development Process Metrics

Personal Information

* Gerekli

1. **Name Surname**
   Name information entered in this field will not be used in the study. You do not have to fill in this field. This field is only required to ensure that unique records are generated.

2. **Number of years of defense industry experience** *
   E.g.: 5 years defense industry experience, 3 years other experience
   Yalnızca bir şıkkı işaretleyin.
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5-10
   - 10+

3. **Number of years of other sector experience** *
   Yalnızca bir şıkkı işaretleyin.
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5-10
   - 10+

4. **Graduated Department** *
   Yalnızca bir şıkkı işaretleyin.
   - CENG
   - EEE
   - ME
   - Diğer:

5. **Working Unit (Department):** *
Yalnızca bir şıkkı işaretleyin.

- Software Simulation
- Software Test
- Software Architectural Design
- Embedded Software

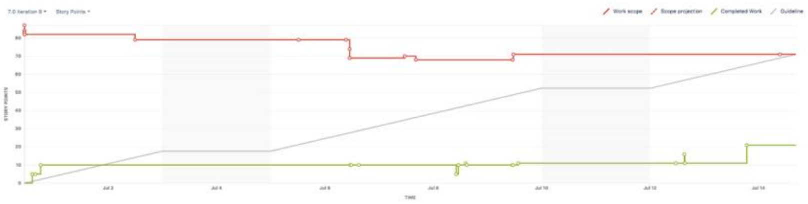
TRAINING: Various metrics are used to evaluate the software development process. (Part 1/4)

Burnup Chart

Track your team's progress towards successful sprint completion by comparing a sprint's completed work with its total scope.

*The vertical axis represents the amount of work. The horizontal axis represents time in days.
*The distance between the lines on the chart is the amount of work remaining. When the project has been completed, the lines will meet.
*Examine the 'Work scope' line to identify any scope creep.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/burnup-chart-945124716.html



Velocity Chart

The Velocity Chart shows the amount of value delivered in each sprint, enabling you to predict the amount of work the team can get done in future sprints. It is useful during your sprint planning meetings, to help you decide how much work you can feasibly commit to.

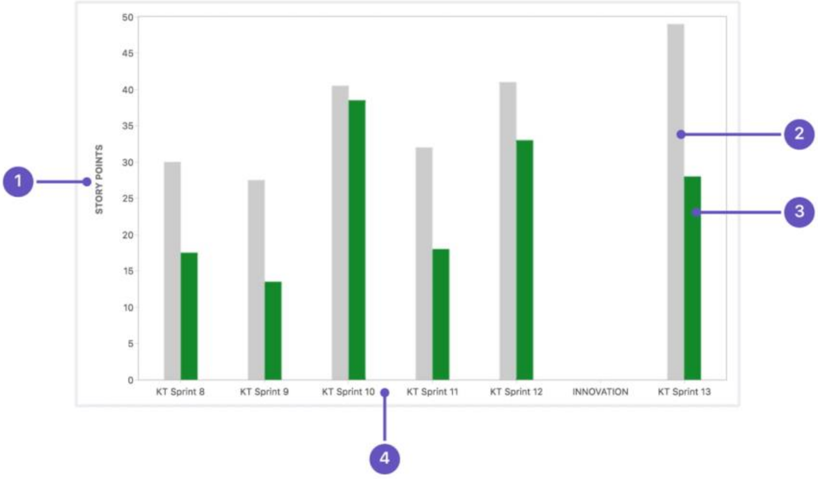
More Info: https://confluence.atlassian.com/jirasoftwarecloud/velocity-chart-777002731.html

1. Estimation statistic: The y-axis displays the statistic used for estimating stories. In the example above, the team is using story points. Estimates can also be based on business value, hours, issue count, or any numeric field of your choice. See Configuring estimation and tracking for more info.

2. Commitment: The gray bar for each sprint shows the total estimate of all issues in the sprint when it begins. After the sprint has started, any stories added to the sprint, or any changes made to estimates, will not be included in this total.

3. Completed: The green bar in each sprint shows the total completed estimates when the sprint ends. Any scope changes made after the sprint started are included in this total.

4. Sprints: The x-axis displays the last 7 sprints completed by the team. This data is used to calculate velocity.



Burndown Chart

Tracks the total work remaining, and projects the likelihood of achieving the sprint goal. This helps your team manage its progress and respond accordingly.

A Burndown Chart shows the actual and estimated amount of work to be done in a sprint. The horizontal x-axis in a Burndown Chart indicates time, and the vertical y-axis indicates cards (issues).

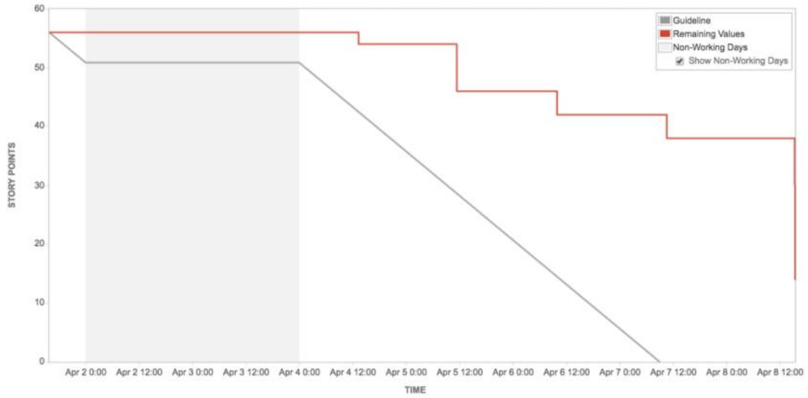
Use a Burndown Chart to track the total work remaining, and to project the likelihood of achieving the sprint goal. By tracking the remaining work throughout the iteration, a team can manage its progress, and respond to trends accordingly. For example, if the Burndown Chart shows that the team may not likely reach the sprint goal, then the team can take the necessary actions to stay on track.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/burndown-chart-777002653.html

Analytics Scrum

Burndown Chart Switch report -

Analytic Sprint 10 - Story Points - How to read this chart

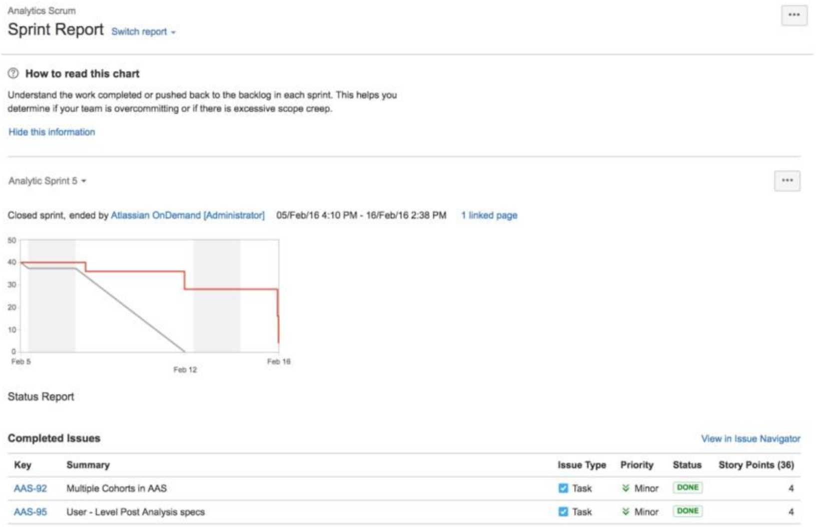


				Story Points		
Date	Issue	Event Type	Event Detail	Inc.	Dec.	Remaining
01/Apr/16 3:47 PM	AAS-135	Sprint start		8		
	AAS-151			8		
	AAS-152			4		
	AAS-153			8		
	AAS-154			4		
	AAS-155			4		
	AAS-156			8		
	AAS-157			8		
	AAS-158			2		
	AAS-159			2		
						56

Sprint Report

The Sprint Report shows the list of issues in each sprint. It is useful for your Sprint Retrospective meetings, and also for mid-sprint progress checks.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/sprint-report-777002722.html



Control Chart

The Control Chart shows the Cycle Time (or Lead Time) for your product, version, or sprint. It takes the time spent by each issue in a particular status (or statuses), and maps it over a specified period of time. The average, rolling average, and standard deviation for this data are shown.

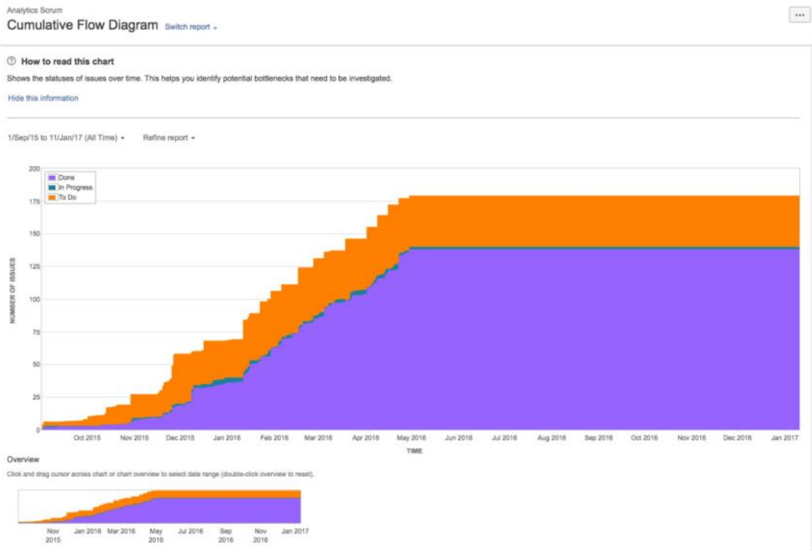
More Info: https://confluence.atlassian.com/jirasoftwarecloud/control-chart-777002660.html

1.Issue details: Select a dot to see data for a specific issue.
2.Zoom in: Highlight an area of the chart to focus on a specific time period.
3.Time scale: Configure the time period you want data for.
4.Refine report: Select the columns, filters, and swimlanes you want data for.

Cumulative Flow Diagram

A Cumulative Flow Diagram (CFD) is an area chart that shows the various statuses of work items for an application, version, or sprint. The horizontal x-axis in a CFD indicates time, and the vertical y-axis indicates cards (issues). Each colored area of the chart equates to a workflow status (i.e. a column on your board).

More Info: https://confluence.atlassian.com/jirasoftwarecloud/cumulative-flow-diagram-777002689.html



Epic Report

The Epic Report shows a list of complete, incomplete, and unestimated issues in an epic. It is particularly useful in planning work for an epic that may extend over multiple sprints.

Use the Epic Report to understand the progress towards completing an epic over time, and to track the amount of remaining work that's incomplete or unestimated.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/epic-report-777002698.html

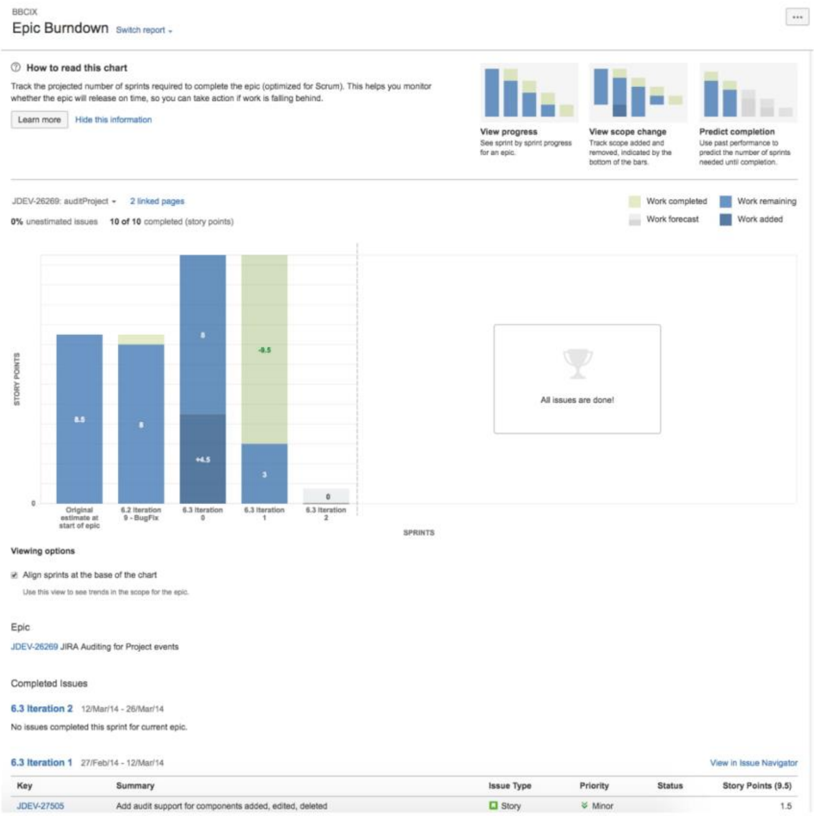
Şu bölüme geçin: "Release Burndown".

TRAINING: Various metrics are used to evaluate the software development process. (Part 2/4)

Epic Burndown Chart

The Epic Burndown report shows you how your team is progressing against the work for an epic. An epic is a large user story that can be broken down into a number of smaller stories. The report will show data based on the estimation statistic that your board is using.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/epic-burndown-777002693.html

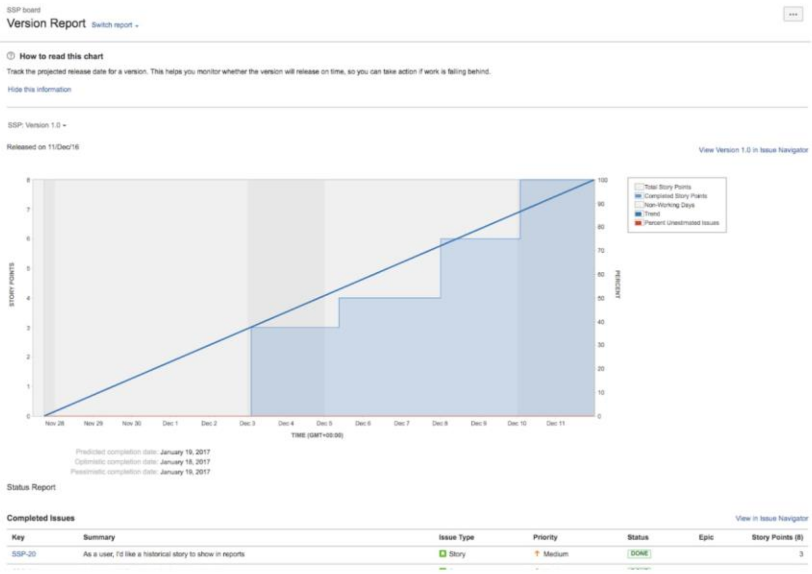


Version Report

The Version Report shows your team's progress towards the completion of a version. The Version Report also shows you the predicted Release Date, based on your team's average rate of progress (velocity) since the start of the version, and the estimated amount of work remaining.

More Info: https://confluence.atlassian.com/jirasoftwarecloud/version-report-777001521.html

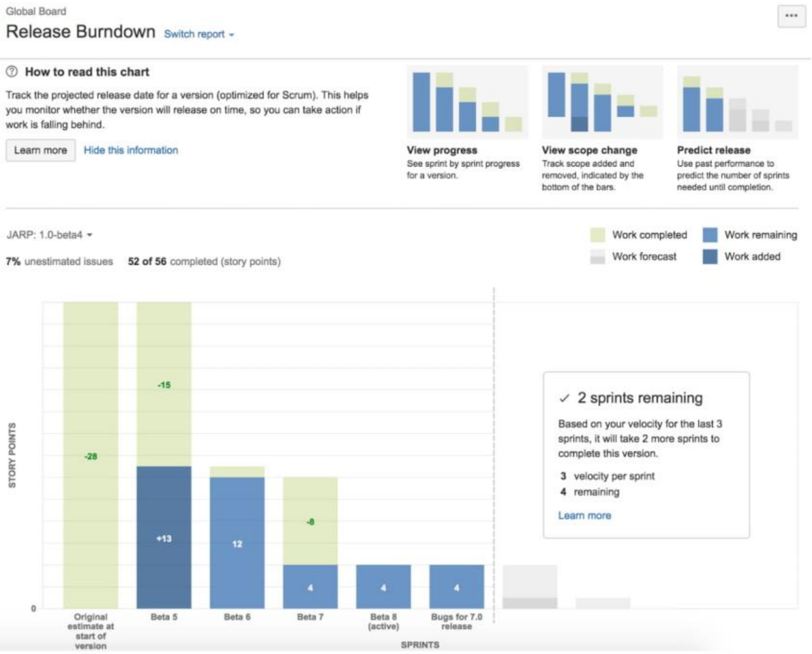
X



Release Burndown

The Release Burndown report shows you how your team is progressing against the work for a release.

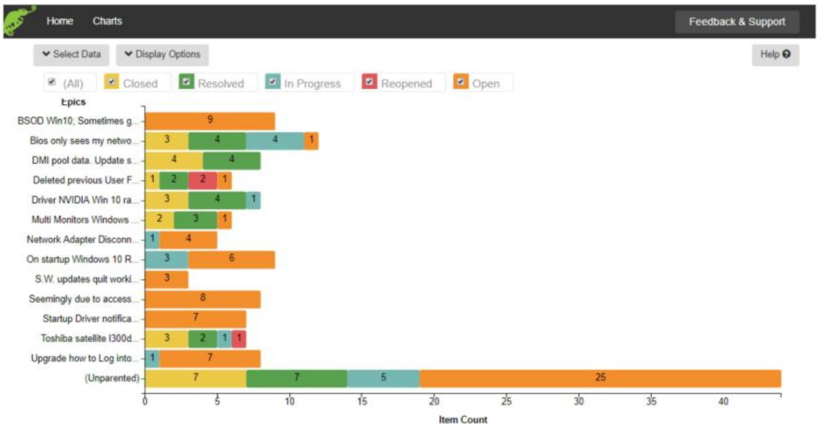
More Info: https://confluence.atlassian.com/jirasoftwarecloud/release-burndown-777002702.html



TRAINING: Various metrics are used to evaluate the software development process. (Part 3/4)

Feature and Epic Progress

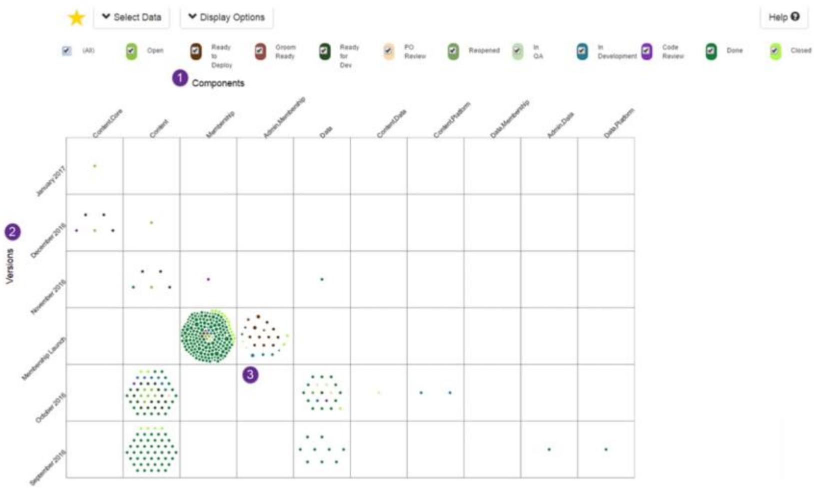
Use this chart to:
Illustrate the relative progress and size of Features within a version or project.
Engage stakeholders with an easily understood representation of the features and their level of progress.
More Info:
https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/5058919/Feature+and+Epic+Progress



Multi-dimensional Backlog

To engage stakeholders in the backlog by making it more comprehensible and providing them with a business perspective that they recognise.

More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/2228252/Multi-dimensional+Backlog



Backlog Map

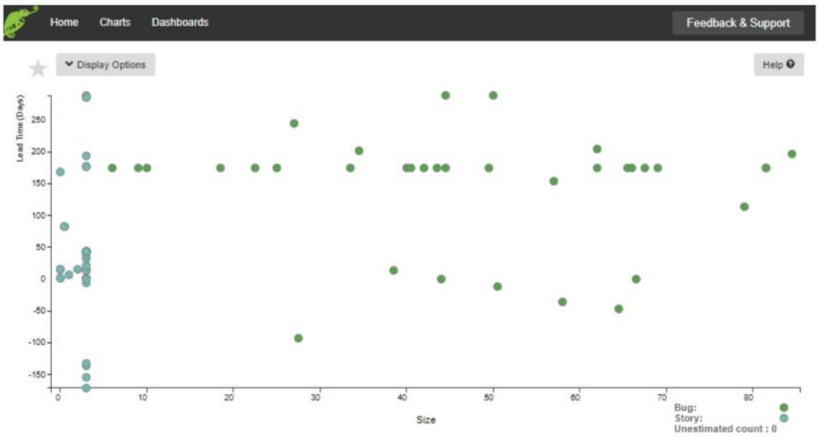
Use this chart to:
Engage stakeholders in the backlog by making it more comprehensible and providing them with a business perspective that they recognise.
Identify work that is in the 'wrong place'.
Review where effort has been spent and where the future focus will be.

More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/6327416/Backlog+Map

Estimate Accuracy

Use this chart to:
See how good your team's estimating has been and whether it's worth trying to improve it.
Good input for retrospectives, where you can focus on some of the outliers to understand the root cause for the correlation between work item size and progression time.

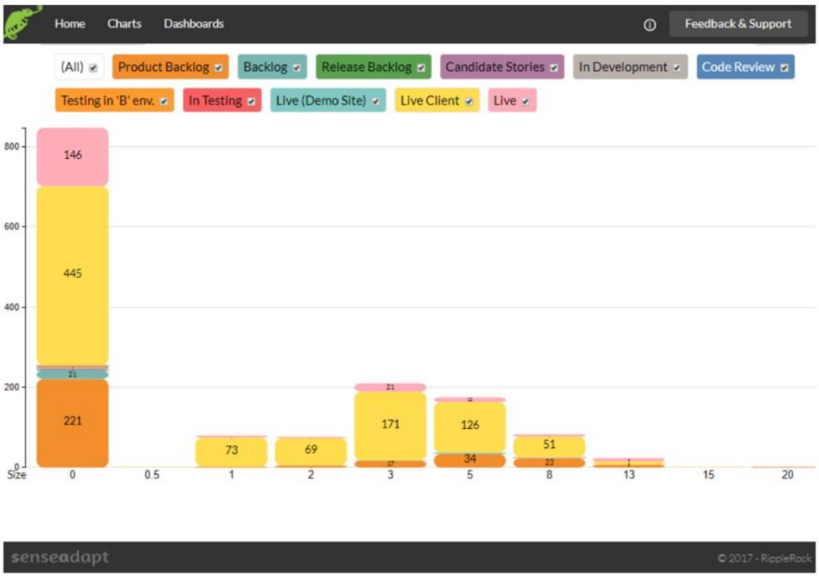
More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/6731680/Estimate+Accuracy



Requirements Readiness

Use this chart to:
Help the team focus on the requirements that need to be sliced smaller to get them ready for development
Review work to see the distribution of sizes of work that have been done or are still in the backlog.
For example to see what proportion of completed work is say a 3 or a 5 (if using story points)
If you have a 'definition of ready' which includes the size of work, then you can see how often this rule has been broken

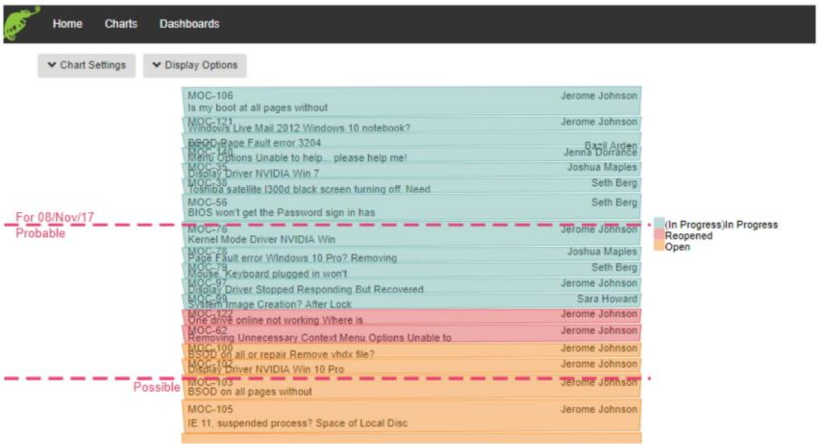
More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/6732127/Requirements+Readiness



Potentially Deliverable Scope

Use this chart to:
Indicate how far down the backlog a team will get by a specified date.
Focus stakeholders' attention on the range of functionality between the probable scope and the possible scope lines.

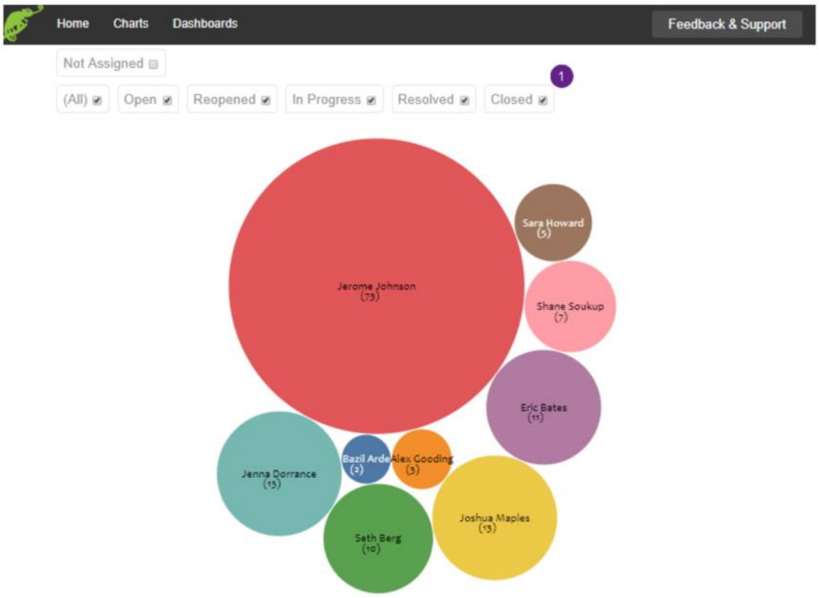
More Info:
https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/6732190/Potentially+Deliverable+Scope



WIP(Work In Progress) by Team Member

Use this chart to:
See which team member is overburdened with work
Review the overall WIP in the team and allocation between members

More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/7204354/WIP+by+Team+Member



Landing Zone Story

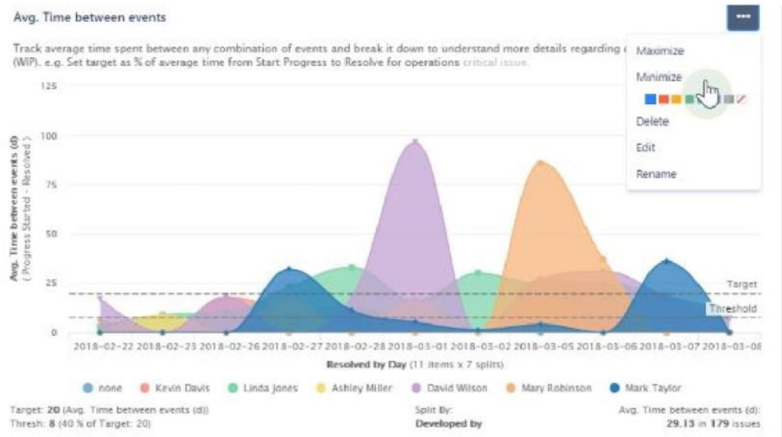
Telling the story of a project is an effective way to engage stakeholders and stimulate the conversations that need to happen on a project. This animated version of the burn-up 'landing zone' chart clearly shows how the likely end dates moved over time, as a result to the changing scope and throughput rate.

More Info: https://ripplerock.atlassian.net/wiki/spaces/SEN/pages/7374657/Landing+Zone+Story

TRAINING: Various metrics are used to evaluate the software development process. (Part 4/4)

Time Between Events

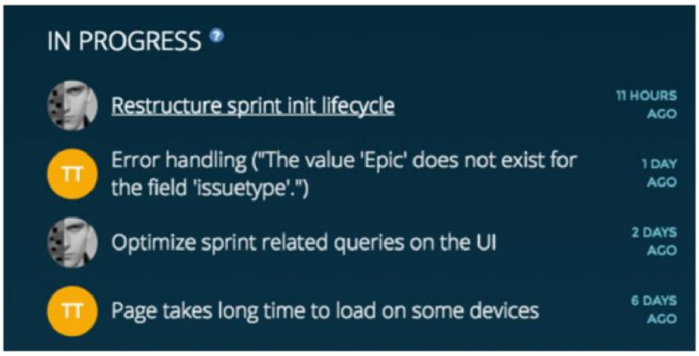
Track average time spent between any combination of events and break it down to understand more details regarding WIP distribution. e.g. Set target as % of average time from Start Progress to Resolve for operations critical issues



Team Status

See what each team member is currently working on and what has been completed recently. What's in review? Is something blocked? This screen is great for communicating what's going on right now in your project.

More Info: https://screenful.com/tour/team-status-screen



Track Lead and Cycle Times

Lead time is the total time that elapses from the creation of a task until its completion.

Reaction time is the time that elapses from the creation of a task until the work is started.

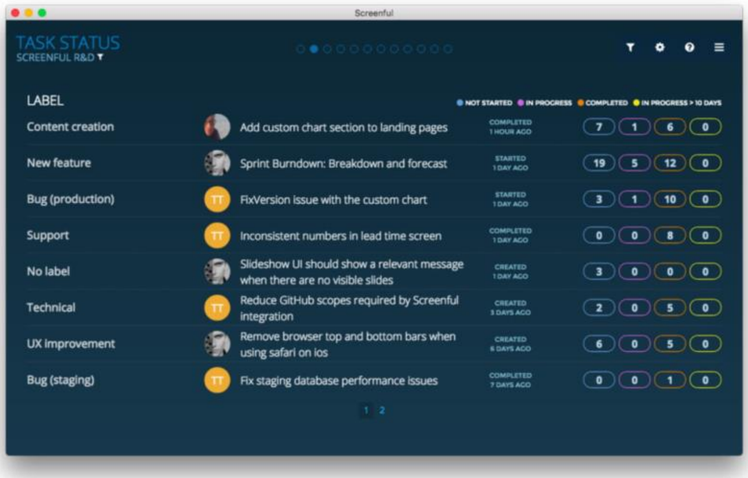
Cycle time is the total time that elapses from the moment when the work is started on a task until its completion.

More Info: https://screenful.com/tour/timing-screen

Task Status (Bird's-Eye View)

Task Status screen allows you to get better view on your open and completed tasks. It allows you to slice and dice your tasks in various ways and quickly find anomalies like the tasks that are blocked or overdue. In addition to seeing total counts, you can also click through to see the individual tasks.

More Info: https://screenful.com/tour/task-status-screen/



Process Metrics Suggestions

We want you to suggest metrics that are best suitable for our software development group.

6. **Which process metrics should be used to evaluate sprints which are in the our scrum process?** *

You can choose multiple. If you have suggestions other than options, please specify the other tab. You can also suggest your own customized process metrics.
Uygun olanların tümünü işaretleyin.

- [ ] Burnup Chart: Provides a visual representation of a sprint's scope, as well as its remaining work. This helps your team stay on track.
- [ ] Velocity Chart: Tracks the amount of work completed from sprint to sprint. This helps you determine your team's velocity, and estimate the work your team can realistically achieve in future sprints.
- [ ] Burndown Chart: Tracks the total work remaining, and projects the likelihood of achieving the sprint goal. This helps your team manage its progress and respond accordingly.
- [ ] Sprint Report: Shows the work completed or pushed back to the backlog in each sprint. This helps you determine if your team is overcommitting or if there is scope creep.
- [ ] Control Chart: Shows the cycle time for your product, version, or sprint. This helps you identify whether data from the current process can be used to determine future performance.
- [ ] Cumulative Flow Diagram: Shows the statuses of issues over time. This helps you identify potential bottlenecks that need to be investigated.
- [ ] Epic Report: Shows the progress towards completing an epic over time. This helps you manage your team's progress by tracking the remaining incomplete and unestimated work.
- [ ] Epic Burndown: Similar to the Epic Report, but optimized for Scrum teams that work in sprints. Tracks the projected number of sprints required to complete the epic. This helps you monitor whether the epic will release on time, so you can take action if work is falling behind.
- [ ] Version Report: Tracks the projected release date for a version. This helps you monitor whether the version will release on time, so you can take action if work is falling behind.
- [ ] Release Burndown: Similar to the Version Report, but optimized for Scrum teams that work in sprints. Tracks the projected release date for a version. This helps you monitor whether the version will release on time, so you can take action if work is falling behind.
- [ ] Feature and Epic Progress: Illustrate the relative progress and size of Features within a version or project.
- [ ] Multi-dimensional Backlog: To engage stakeholders in the backlog by making it more comprehensible and providing them with a business perspective that they recognise.
- [ ] Backlog Map: Identify work that is in the 'wrong place'.
- [ ] Estimate Accuracy: See how good your team's estimating has been and whether it's worth trying to improve it.
- [ ] Requirements Readiness: Help the team focus on the requirements that need to be sliced smaller to get them ready for development
- [ ] Potentially Deliverable Scope: Indicate how far down the backlog a team will get by a specified date.
- [ ] WIP(Work In Progress) by Team Member: See which team member is overburdened with work
- [ ] Landing Zone Story: Telling the story of a project is an effective way to engage stakeholders and stimulate the conversations that need to happen on a project.
- [ ] Time Between Events: Track average time spent between any combination of events and break
- [ ] Team Status: See what each team member is currently working on and what has been completed recently.
- [ ] Track Lead and Cycle Times: total time that elapses from the moment when the work is started on a task until its completion.
- [ ] Task Status (Bird's-Eye View): Task Status screen allows you to get better view on your open and completed tasks.
- [ ] Diğer: ____________________

Part II

Appendix A

Appendices

The Resuls of AHP Implementation

1. Experience	>=9.5	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Feasib.&Usab.
2. Experience	>=9.5	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
3. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	>=9.5	No comp.	Relevance
4. Feasib.&Usab.	>=9.5	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
5. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	>=9.5	No comp.	Relevance
6. Functionality	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	>=9.5	No comp.	Relevance

Pairwise comparison of the criteria by Expert 1

1. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	>=9.5	No comp.	Feasib.&Usab.
2. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	>=9.5	No comp.	Functionality
3. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	>=9.5	No comp.	Relevance
4. Feasib.&Usab.	>=9.5	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
5. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	>=9.5	No comp.	Relevance
6. Functionality	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	**8**	9	>=9.5	No comp.	Relevance

Pairwise comparison of the criteria by Expert 2

1. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	>=9.5	No comp.	Feasib.&Usab.
2. Experience	>=9.5	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
3. Experience	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	>=9.5	No comp.	Relevance
4. Feasib.&Usab.	>=9.5	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
5. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	>=9.5	No comp.	Relevance
6. Functionality	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	>=9.5	No comp.	Relevance

Pairwise comparison of the criteria by Expert 3

1. Experience	>=9.5	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Feasib.&Usab.
2. Experience	>=9.5	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
3. Experience	>=9.5	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	>=9.5	No comp.	Relevance
4. Feasib.&Usab.	>=9.5	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
5. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	>=9.5	No comp.	Relevance
6. Functionality	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	>=9.5	No comp.	Relevance

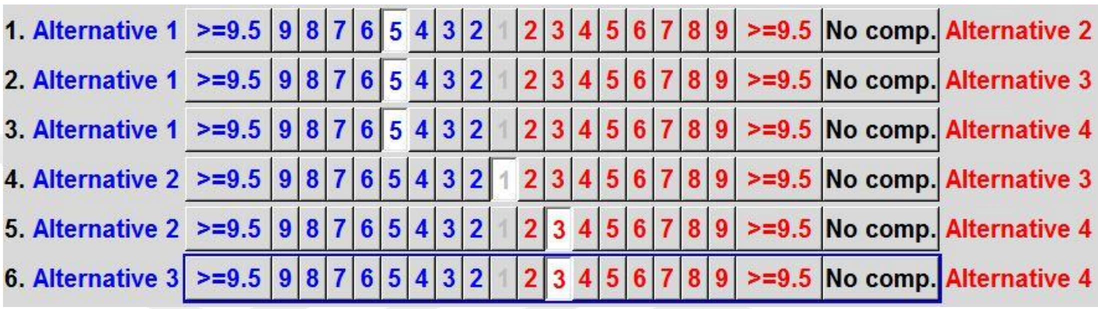
Pairwise comparison of the criteria by Expert 4

1. Experience	>=9.5	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Feasib.&Usab.
2. Experience	>=9.5	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
3. Experience	>=9.5	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	>=9.5	No comp.	Relevance
4. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	>=9.5	No comp.	Functionality
5. Feasib.&Usab.	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	>=9.5	No comp.	Relevance
6. Functionality	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	>=9.5	No comp.	Relevance

Pairwise comparison of the criteria by Expert 5

Pairwise comparison of the criteria by Expert 6

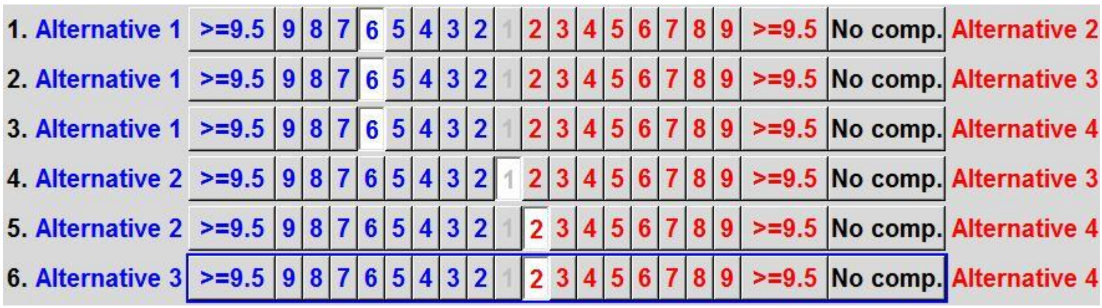
Evaluation of Alternatives by Expert 1:



Pairwise comparison of the alternatives in terms of **experience** by Expert 1

Normalized values of alternatives in terms of **experience**

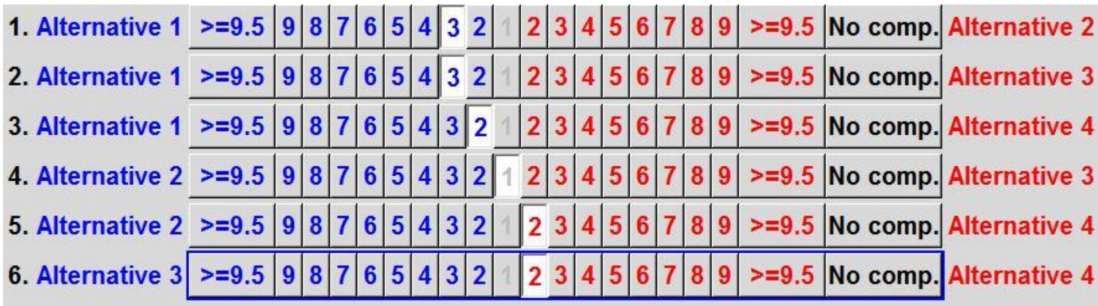
Alternatives	Normalized
Alternative 1	0.61315828941341388
Alternative 2	0.089175418879090695
Alternative 3	0.089175418879090695
Alternative 4	0.2084908728284047



Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 1

Normalized values of alternatives in terms of **feasibility&usability**

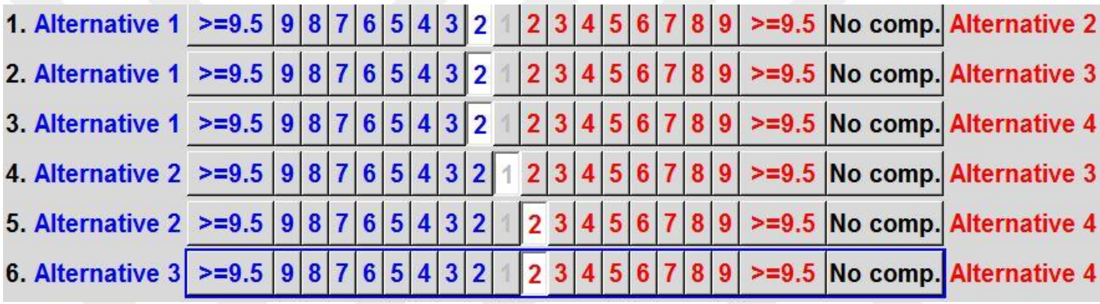
Alternatives	Normalized
Alternative 1	0.66220436374511737
Alternative 2	0.091243847974162962
Alternative 3	0.091243847974162962
Alternative 4	0.15530794030655681



Pairwise comparison of the alternatives in terms of **functionality** by Expert 1

Normalized values of alternatives in terms of **functionality**

Alternatives	Normalized
Alternative 1	0.4554079638693641
Alternative 2	0.14087958377799481
Alternative 3	0.14087958377799481
Alternative 4	0.26283286857464638



Pairwise comparison of the alternatives in terms of **relevance** by Expert 1

Normalized values of alternatives in terms of **relevance**

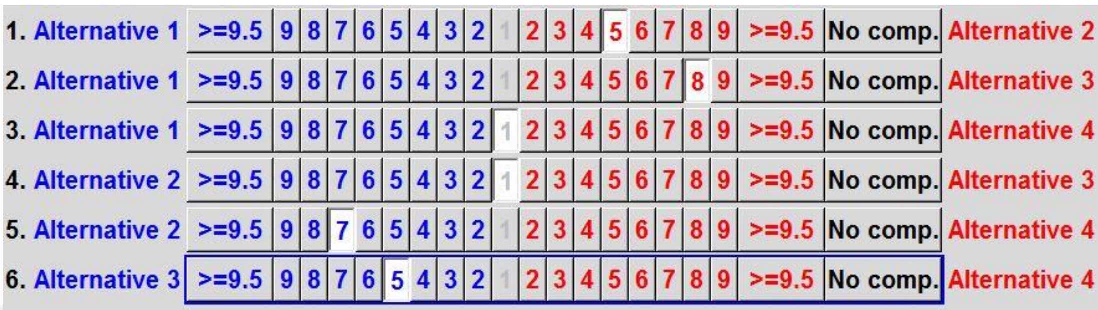
Alternatives	Normalized
Alternative 1	0.39520638153784521
Alternative 2	0.1633641499651548
Alternative 3	0.1633641499651548
Alternative 4	0.27806531853184518

Evaluation of Alternatives by Expert 2:

Pairwise comparison of the alternatives in terms of **experience** by Expert 2

Normalized values of alternatives in terms of **experience**

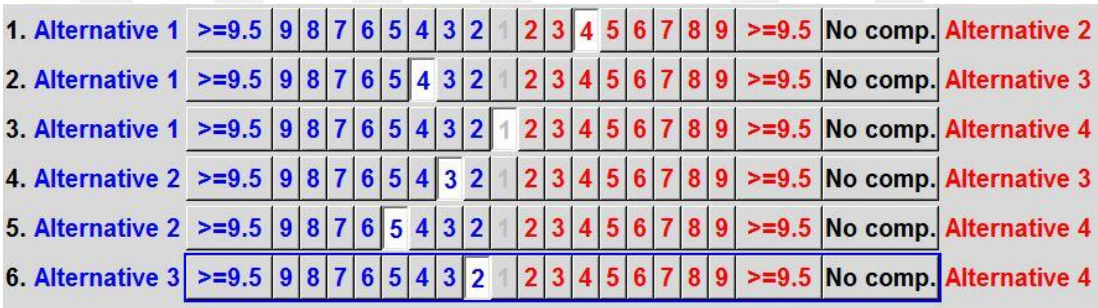
Alternatives	Normalized
Alternative 1	0.36351412149637419
Alternative 2	0.14579671413394604
Alternative 3	0.43555379872650468
Alternative 4	0.055135365643175178



Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 2

Normalized values of alternatives in terms of **feasibility&usability**

Alternatives	Normalized
Alternative 1	0.069164909672301059
Alternative 2	0.42173332763032578
Alternative 3	0.4377759642680854
Alternative 4	0.071325798429287782



Pairwise comparison of the alternatives in terms of **functionality** by Expert 2

Normalized values of alternatives in terms of **functionality**

Alternatives	Normalized
Alternative 1	0.22244565453390 34
Alternative 2	0.53211288777151333
Alternative 3	0.13204012270986812
Alternative 4	0.11340242406522831

Sample manuel stepwise calculation:

Functionality	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Alternative 1	1	1/4	4	1
Alternative 2	4	1	3	5
Alternative 3	1/4	1/3	1	2
Alternative 4	1	1/5	1/2	1
Sum ∑	**6.25**	**1.78**	**8.50**	**9.00**

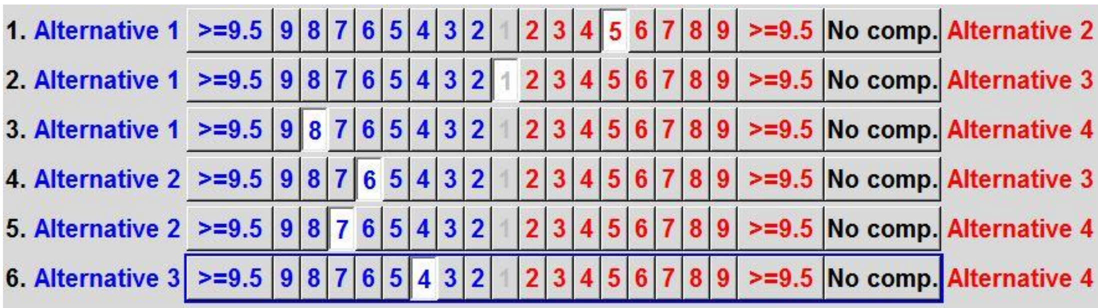
Normalized Matrix	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Sum ∑ / 4
Alternative 1	1/(6.25)	1/4/(1.78)	4/(8.50)	1/(9.00)	**0.22**
Alternative 2	4/(6.25)	1/(1.78)	3/(8.50)	5/(9.00)	**0.53**
Alternative 3	1/4/(6.25)	1/3/(1.78)	1/(8.50)	2/(9.00)	**0.14**
Alternative 4	1/(6.25)	1/5/(1.78)	1/2/(8.50)	1/(9.00)	**0.11**
Sum ∑	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Pairwise comparison of the alternatives in terms of **relevance** by Expert 2

Normalized values of alternatives in terms of **relevance**

Alternatives	Normalized
Alternative 1	0.081245539952225609
Alternative 2	0.20307408522186771
Alternative 3	0.66340900934410518
Alternative 4	0.052271365481801481

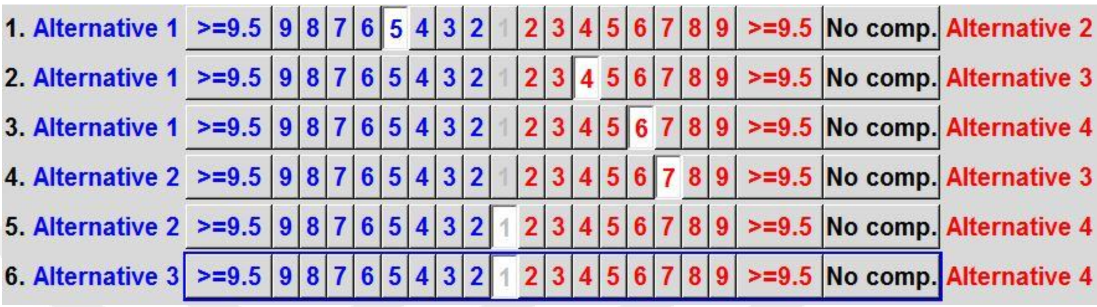
Evaluation of Alternatives by Expert 3:



Pairwise comparison of the alternatives in terms of **experience** by Expert 3

Normalized values of alternatives in terms of **experience**

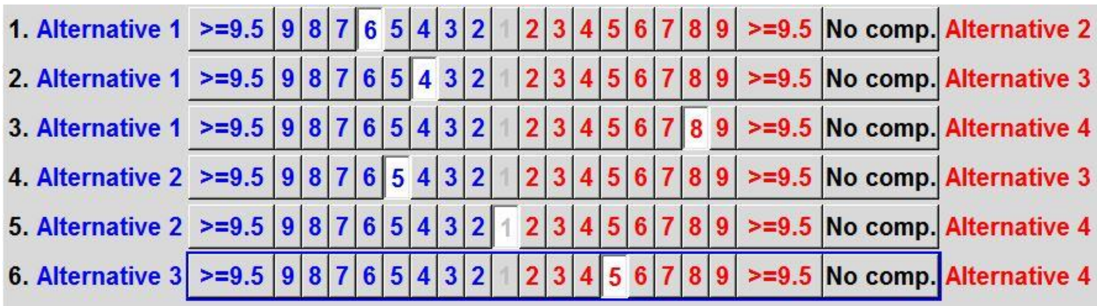
Alternatives	Normalized
Alternative 1	0.1868483438221073
Alternative 2	0.6277279436411539
Alternative 3	0.14092096101289411
Alternative 4	0.044502751523883263



Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 3

Normalized values of alternatives in terms of **feasibility&usability**

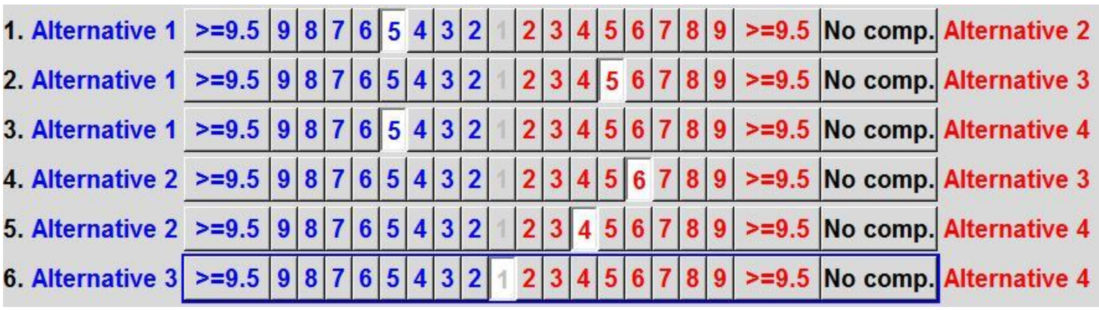
Alternatives	Normalized
Alternative 1	0.157526035635734
Alternative 2	0.1018376616471985
Alternative 3	0.39863095732790321
Alternative 4	0.34200534538916427



Pairwise comparison of the alternatives in terms of **functionality** by Expert 3

Normalized values of alternatives in terms of **functionality**

Alternatives	Normalized
Alternative 1	0.26286680900333398
Alternative 2	0.16686770665334549
Alternative 3	0.043332785787544827
Alternative 4	0.52693269855577574



Pairwise comparison of the alternatives in terms of **relevance** by Expert 3

Normalized values of alternatives in terms of **relevance**

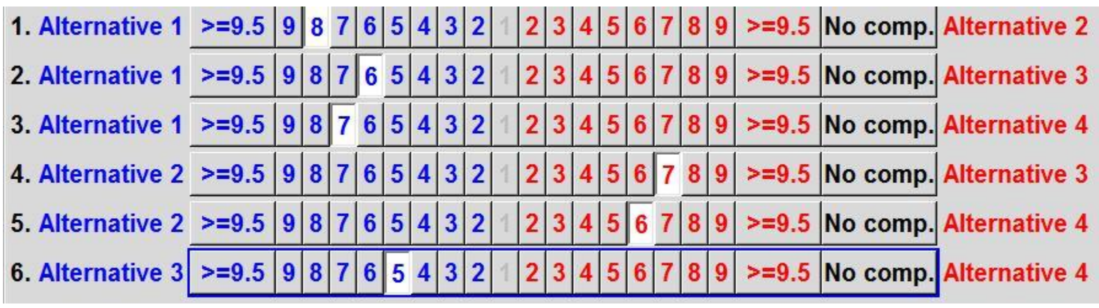
Alternatives	Normalized
Alternative 1	0.29838466688479143
Alternative 2	0.045337919687899304
Alternative 3	0.47877155445670377
Alternative 4	0.17750585897060547

Evaluation of Alternatives by Expert 4:

Pairwise comparison of the alternatives in terms of **experience** by Expert 4

Normalized values of alternatives in terms of **experience**

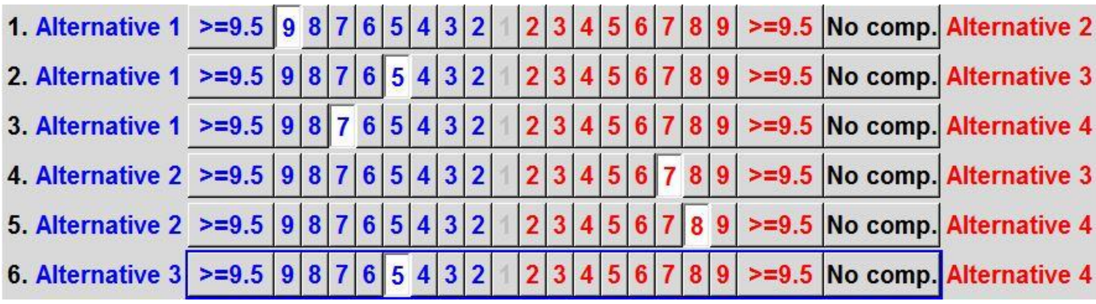
Alternatives	Normalized
Alternative 1	0.63987508650146918
Alternative 2	0.077644051431612252
Alternative 3	0.243789804178521
Alternative 4	0.038691057888397593



Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 4

Normalized values of alternatives in terms of **feasibility&usability**

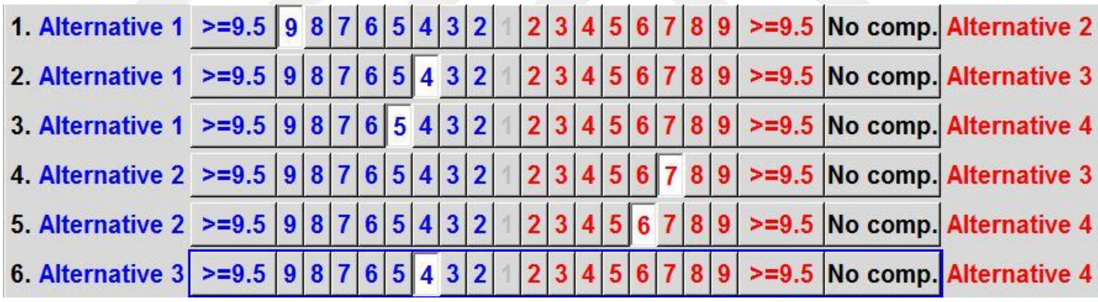
Alternatives	Normalized
Alternative 1	0.63967373091706525
Alternative 2	0.035345970427747286
Alternative 3	0.22903597650106305
Alternative 4	0.095944322154124351



Pairwise comparison of the alternatives in terms of **functionality** by Expert 4

Normalized values of alternatives in terms of **functionality**

Alternatives	Normalized
Alternative 1	0.61774801346920216
Alternative 2	0.031992157233305757
Alternative 3	0.24265025356318282
Alternative 4	0.10760957573430932



Pairwise comparison of the alternatives in terms of **relevance** by Expert 4

Normalized values of alternatives in terms of **relevance**

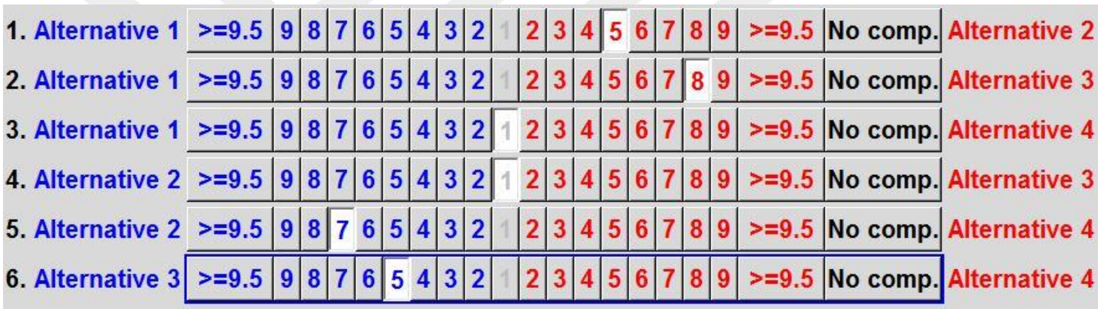
Alternatives	Normalized
Alternative 1	0.58421332072885468
Alternative 2	0.03628695389087596
Alternative 3	0.26057269938054406
Alternative 4	0.11892702599972542

Evaluation of Alternatives by Expert 5:

Pairwise comparison of the alternatives in terms of **experience** by Expert 5

Normalized values of alternatives in terms of **experience**

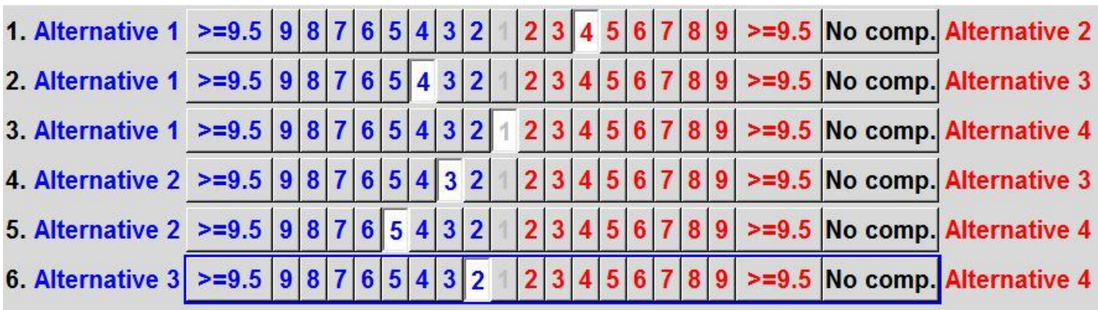
Alternatives	Normalized
Alternative 1	0.627803536992752 26
Alternative 2	0.08285370156829718 9
Alternative 3	0.12996486972570631
Alternative 4	0.15937789171324421



Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 5

Normalized values of alternatives in terms of **feasibility&usability**

Alternatives	Normalized
Alternative 1	0.124999914062477
Alternative 2	0.37500002343749561
Alternative 3	0.124999945312479
Alternative 4	0.37500011718754828



Pairwise comparison of the alternatives in terms of **functionality** by Expert 5

Normalized values of alternatives in terms of **functionality**

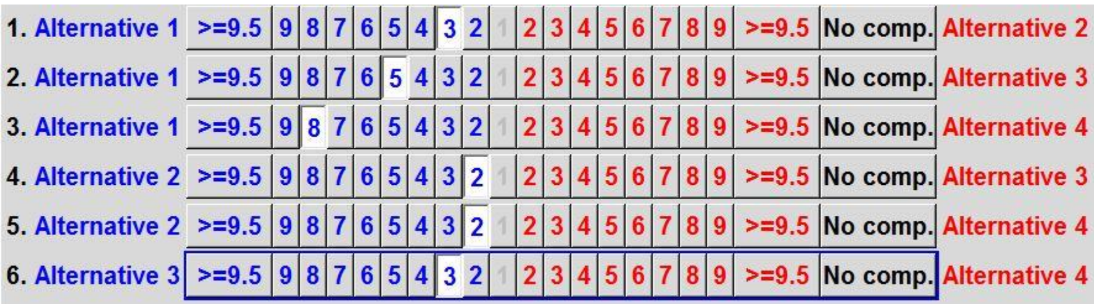
Alternatives	Normalized
Alternative 1	0.21000128118578959
Alternative 2	0.21000128118578959
Alternative 3	0.051878233274919659
Alternative 4	0.52811920435350124

Pairwise comparison of the alternatives in terms of **relevance** by Expert 5

Normalized values of alternatives in terms of **relevance**

Alternatives	Normalized
Alternative 1	0.3125
Alternative 2	0.3125
Alternative 3	0.0625
Alternative 4	0.3125

Evaluation of Alternatives by Expert 6:



Pairwise comparison of the alternatives in terms of **experience** by Expert 6

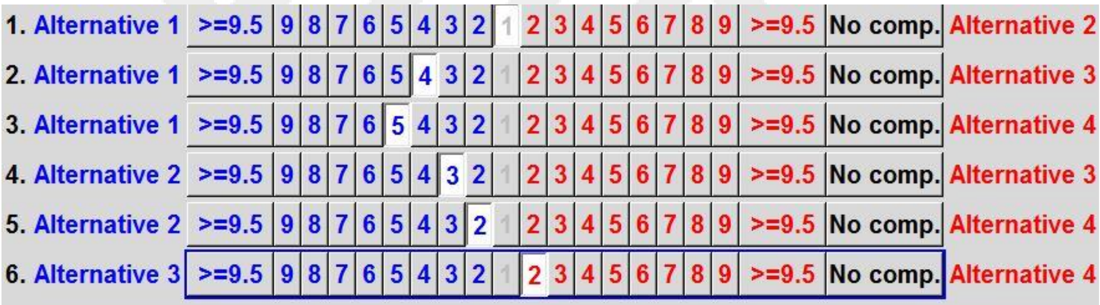
Normalized values of alternatives in terms of **experience**

Alternatives	Normalized
Alternative 1	0.59386472951137059
Alternative 2	0.19771592246154035
Alternative 3	0.13796411829989783
Alternative 4	0.07045522972719126

Pairwise comparison of the alternatives in terms of **feasibility&usability** by Expert 6

Normalized values of alternatives in terms of **feasibility&usability**

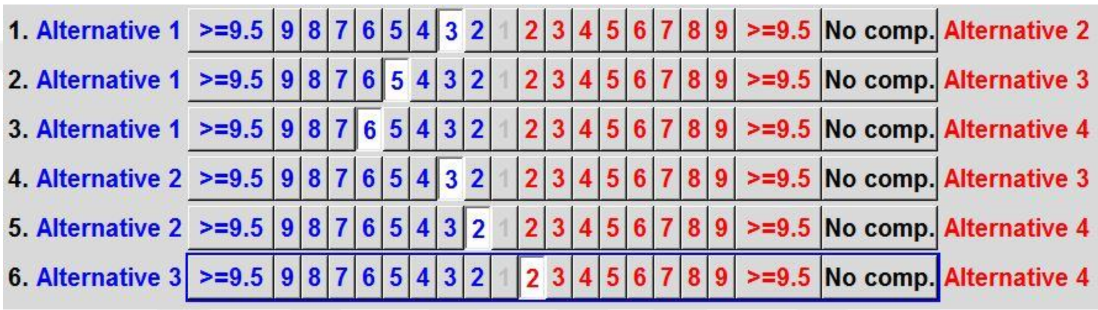
Alternatives	Normalized
Alternative 1	0.56439990842910837
Alternative 2	0.225656655297479
Alternative 3	0.082338629767485016
Alternative 4	0.12760480650592759



Pairwise comparison of the alternatives in terms of **functionality** by Expert 6

Normalized values of alternatives in terms of **functionality**

Alternatives	Normalized
Alternative 1	0.4460103008535784
Alternative 2	0.32177780356701036
Alternative 3	0.092579111059563138
Alternative 4	0.13963278451984798



Pairwise comparison of the alternatives in terms of **relevance** by Expert 6

Normalized values of alternatives in terms of **relevance**

Alternatives	Normalized
Alternative 1	0.57957533690321938
Alternative 2	0.21968106757297781
Alternative 3	0.080969578510349541
Alternative 4	0.11977401701345319