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EVALUATING THE EFFECTIVENESS OF WATERFALL AND AGILE PROJECT MANAGEMENT METHODOLOGIES IN PROVIDING DETECTED TIME, COST AND QUALITY METRICS IN SOFTWARE PROJECTS

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MASTER THESIS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Aydın Gökhan KAHRAMAN

DEDICATION

This thesis is dedicated to my deceased mom İlhan, my wife Merve, my brother Hakan, my father Mehmet and rest of my family.

Aydın Gökhan KAHRAMAN

ABSTRACT

EVALUATING THE EFFECTIVENESS OF WATERFALL AND AGILE PROJECT MANAGEMENT METHODOLOGIES IN PROVIDING DETECTED TIME, COST AND QUALITY METRICS IN SOFTWARE PROJECTS

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Software is a command sequence that consists of a meaningful array of values 1 and 0 and is used in many areas such as computer, machine, system, and device or product management. Software is taking place more and more in human life day by day, and many of the usual work in any coding language prepared by running commands from the software and the services and products put forward by increasing the rate of realization. Shaping the new habits of humanity with software based phenomena is the most important sign of the digital transformation experienced by all human beings. Today, humanity uses software in every field that it can associate with health, communication, finance, media, transportation, tourism, real estate, marketing, sports, defense, production, agriculture, geography, meteorology, games and more.

A project is a collection of temporary joint efforts that are step by step matured in a given time interval and active for a specific purpose, measured and determined at the beginning of the objectives and output expectations. With the creation of mankind, the project takes place in our lives as a process that depends on many variables, the most basic requirements of which are survival, nutrition, shelter and success or failure. Humanity first defined the project and then formed the index of rules that could manage this definition and formed the basis of project management.

All known software production activities are progressing as individual or a team project. The information in software field and number of experienced professionals increase continuously. As a result of these progresses, the number of projects is increasing and magnitude of budgets is enhanced. As a result of these developments, the question about whether there is a relationship between the project management methodology used and project performance metrics (cost, time, quality) and the question about which one of waterfall and agile project management methodologies is more effective in ensuring success with regards to these three metrics (project cost, time, quality) have been raised.

A survey methodology was used to find answers to the two main questions above. The survey has been answered by 210 software professionals or professionals whose current jobs are related with software. The responses from 161 out of 210 respondents who have experience in both agile and waterfall methods were used in the data analysis phase of the thesis. Results showed that there are statistically significant differences between agile and waterfall project techniques in terms of cost, time and quality metrics.

Keywords: Project, Project Management, Project Performance, Software, Software Projects, Agile, Waterfall, Cost, Quality, Time

ÖZET

ŞELALE VE ÇEVİK PROJE YÖNETİM METODLARININ ZAMAN, MALİYET VE KALİTE METRİKLERİNİ SAĞLAMAKTAKİ ETKİNLİĞİNİN DEĞERLENDİRİLMESİ

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Yazılım, temelinde 1 ve 0 değerlerinin anlamlı bir dizi oluşturmasından oluşan, bilgisayar, makine, sistem, cihaz ya da ürün yönetimi gibi işlemlerde ve pek çok alanda kullanılan komut dizinidir. Yazılım insan hayatında günden güne daha fazla yer tutmakta ve alışılageldik pek çok işimizi herhangi bir kodlama dilinde hazırlanmış yazılımlardan gelen komutlar ile çalıştırılarak ortaya konulmuş hizmet ve ürünlerle gerçekleştirme oranımız artmaktadır. İnsanlığın sahip olduğu yeni alışkanlıkların yazılım tabanlı olgular ile şekillenmesi tüm insanların yaşadığı sayısal dönüşümün de en önemli işaretidir. Günümüzde insanlık sağlık, iletişim, finans, medya, ulaşım, turizm, gayrimenkul, pazarlama, spor, savunma, üretim, tarım, coğrafya, meteoroloji, oyun ve ilişkilendirebileceği her alanda yazılımı her geçen gün daha da büyüyen bir oranla kullanmaktadır.

Proje, özel bir amaç uğruna belirli bir zaman diliminde ve aktif olduğu süreçte adım adım olgunlaşan, hedeflerinin ve çıktı beklentilerinin başlangıcında ölçümlenip tespit edildiği geçici ortak çabalar toplamıdır. Proje insanlığın yaratılışıyla ile birlikte en temel gereksinimleri olan hayatta kalma, beslenme, barınmadan itibaren kendini gösteren ve başarılı ya da başarısız olarak sonuçlanması pek çok değişkene bağlı olan bir süreç olarak hayatımızda yer almaktadır. İnsanlık öncelikle projeyi tanımlamış daha sonra da bu tanımı yönetebilecek kurallar dizinini oluşturarak proje yönetiminin de temellerini oluşturmuştur.

Bilinen tüm yazılım üretim faaliyetleri bireysel ya da ekip çalışması olarak bir proje şeklinde ilerlemektedir. Yazılım konusunda bilginin ve deneyimli profesyonellerin ve yürütülen projelerin sayısı zaman içinde sürekli artmaktadır. Bu artışlar ile beraber bütçelerin de büyümesi,

hem kullanılan proje yönetim yönteminin projenin zaman, maliyet ve kalite yönünde etkisi olup olmadığı hem de var olan proje yönetim metotlarından hangisi ile en etkin sonuçların alındığı sorularını da beraberinde getirmiştir.

Yukarıda bahsedilen iki ana soruya yanıt bulunması amacıyla anket yöntemi kullanılmıştır. Bu ölçümlemeyi yapabilmek adına yazılım üreten ya da yazılım alanında iş yapan 210 profesyonelden anket yoluyla cevapları alınmış, hem Çevik hem de Şelale yöntemlerinde tecrübe sahibi olan 161 kişi tarafından cevaplandırılan anket sonuçları üzerine yapılan değerlendirme ile varılan sonuçlar bu tezin hazırlanmasında kullanılmıştır. Yapılan değerlendirme sonucunda proje yönetimi metodu ile projenin zaman, maliyet ve kalite ölçütleri arasında ilişki olduğu ortaya çıkmıştır.
Anahtar kelimeler: Proje, Proje Yönetimi, Proje Performansı, Yazılım, Yazılım Projeleri, Çevik, Şelale, Maliyet, Kalite, Zaman

CONTENTS

ABBREVATIONS

SPSS : Statistical Package for Social Sciences
ANOVA : Analysis of Variance
TDK : Türk Dil Kurumu
PMI : Project Management Institute
PMI PMBOK ® 6 : Project Management Institute Project Management Body of Knowledge 6
EVM : Earned Value Management
PV : Planned Value
EV : Earned Value
AC : Actual Cost
BAC : Budget at Completion
EAC : Estimation at Completion
ETC : Estimation to Completion
VAC : Variance at Completion
TCPI : To Completion Performance Index
SV : Schedule Variance
SPI : Schedule Performance Index
CPI : Cost Performance Index
CV : Cost Variance
XP : Extreme Programming
ASD : Adaptive Software Development
FDD : Feature Driven Development
LSD : Lean Software Development
DSDM : Dynamic Software Development Method
IEEE : The Institute of Electrical and Electronics Engineers
SDLC : Software Development Life Cycle
SWEBOK : Software Engineering Book
p : Statistical Hypothesis Test Probability Value
VIF : Variance Inflation Factor
N : Main mass
df : Degree of Freedom
KMO : Kaiser-Meyer-Olkin

TABLE LIST

FIGURE LIST

FORMULA LIST

1. PROJECT

1.1 Definition of Project

Project and project management are related to many sectors, information area and institution. Albayrak (2011) argued in his book that the project is an approach which is based on system, product or service development. So, project is called as the activities which are done with the scope, time and budget restrictions. As stated in PMI PMBOK ® 6 project is a struggle which is not repeating and it targets to form a sole outcome. Project has basic characteristics that, having defined and peerless aim and target in certain start and end timeline and being transitory, formed from dedicated human resources and special resources. As a result of these characteristics, the project has exacted and approved scope and actual restrictions. Project does not contain repetitive transactions which are called as operation; it aims to bring forth a newly designed, constructed, prepared product, service or result. A project can be terminated in the following ways: First, when it reaches the demanded targets. Second, when it is understood that the project is not going to meet the targets, there is no need to complete the project because of targets becoming obsolete. And also, a project can be finished with the demand of customer or sponsor. For a project, being temporary cannot show the project is based on a short time period; on the contrary, a project can take years or decades in execution or the product or service which is result of a project can be used for a long time period or has societal, scientific, environmental and economic affects which is so longer than the it's execution period. Time issues for any project are related with commercial, performance and agreement cases, and indicate the validation of project. (Project Management Institute (PMI), 2018)

Projects have been executed to produce specific, private and constant results. In contrast to project process as being temporary, permanence is the essence in the results of project. And generally, this is one of the basic targets of project and independent from project area or sector. The outcome of the project could be formed from abstract or concrete results. There can be several deliveries to complete whole project outcomes and some of the deliveries can be similar or repetitive of each other. However, in case this situation does not cause a conflict with being unique principle of project or this situation does not change this principle. For example, constructing a skyscraper with phases is delivering floors which contain residences or offices to the owner at each delivery and there can be used same kind and amount of materials and same

project team. But this is not repetitive because at each floor or delivery phase the customers, conditions or design can be different. As a result, the skyscraper is unique with its design, plan and location, and that makes the project unique as well. Although projects are in various sectors with different budget and schedule plans, such as a tunnel construction, a new and creative mobile application development, a chemical material creation, it is aimed being under or equal to budget and delivering on time or earlier by project team members. Projects are executed at each levels of organization, one person or more than one people and one organization or more organizations with different units can be included in a single project. Projects can be new for the project team members when it compares with on-going routine works, so projects require detailed and specific planning. (Project Management Institute (PMI), 2018)

It is mentioned in Head First PMP being time-boxed, aiming to produce a private outcome and having gradual maturity are common properties of projects, besides all projects cannot be strategic and prominent, and each of the executed projects cannot be accomplished every time and is not running-on operations. (Greene & Stellman, 2019)

The project as stated by Blackstone Jr. and Schleier Jr. (2009), is a process which is unique and has specific target, with time and cost limitations to produce an outcome. And also, they have stated that, each project has different tasks which have relationships directly or indirectly each other and any delay in any task affects the rest of the works and can cause the late delivery of the project results or cancellation of the whole project. It is argued by Blackstone Jr. and Schleier Jr. (2009) that the created work breakdown structure, task relations with resource facilities, task estimations are the elements of forming the critical chain and that shows the project total time duration. Critical chain has no floats; so on the case of any delaying on the critical chain automatically exceeds the project timeline. As the first step of project manager should be doing planning again. (Blackstone Jr, Cox, & Schleier Jr, 2009)

Kerzner (2013) stated that the 5 processes of project and defined the project management as the planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives.
(Kerzner, 2013)

1.2 Project Size Determination

Project size is classified as three types according to their magnitude. Large type projects are time-boxed between 6 and 24 months usually and bring important changes on product or re-construction has big amount of risk and complexity. Medium type projects take 3-6 months' timeline, has medium level risk and complexity, partially new and unknown work is involved to the scope. Small type projects are shorter than 3 months, generally no new feature or work package is involved to the scope, and there are less risk and complexity at the scope. (Oregon State University, 2017)

It is also argued that project types are sized by budget and time metrics with numeration from 1 to 5 first and then a second evaluation is done according to risks for number of team members, number of workgroups, technology knowledge, complexity, political impact, deployment impact with the same numeration technique for each metrics and total of numbers for 6 metrics. As a result of second evaluation the first sizing can be increased or stayed same. (UNM Information Technologies, 2016)

Project size classification according to time and budget parameters is presented in Table 1 below.

Table 1 : Project Classification – Sizing Matrix

Project Classification – Sizing Matrix		
Project Size	Time (Hours)	Budget
1	<100	<$3000
2	100-300	$3000-$10000
3	300-600	$10000-$25000
4	600-5000	$25000-$150000
5	>5000	>$150000

Risk is calculated according to Table 2 below. (UNM Information Technologies, 2016),

Table 2: Project Classification – Risk Matrix

Project Classification - Risk Matrix					
Risk Factor	Low (0)	Medium (1)	High (2-3)	Very High (4-5)	Total Score
Total Team Size	<5	5-9	10-14	>14	(0-5)
Workgroups Involved	1-2	3-4	5-6	>6	(0-5)
Technology	Expert	Familiar	New	Breakthrough	(0-5)
Complexity	No complexity	Less Complexity	Multiple solutions exists	Vaguely	(0-5)
Political Impact	Unit/Dept	Director	VP/Dean	UNM-wide	(0-5)
Deployment Impact	Unit/Dept	Director	VP/Dean	UNM-wide	(0-5)
Risk Scoring	0-10: Managable (No change on Project size) 11-20: Moderate (Add 1 to Project Level) 21-30: High (Add 2 to Project Level)				

1.3 Project Operation Comparison

It is claimed that there are two main work types in organizations: first one is project work which aims to create a unique service or product and second one is operational work which is combined by the repetitive issues after project completion, and business, system, and organizational activities. As operational work is a successor of project work, two work types are closely related to each other. When project outcome is released and it meets enough success criteria to operate, operational work begins focusing on keeping the system, product or service alive. (RMC Publications, Inc., 2018)

1.4 Project Constraints

It is claimed by PMI PMBOK® 6 that there are three constraints of projects and the scope of the project is affected by any change in these constraints. The constraints are time, cost and quality. These are the boundaries of scope like a triangle, and the scope is restricted by these constraints. (Project Management Institute (PMI), 2018)

The triangle of constraints is shown in Figure 1 below;

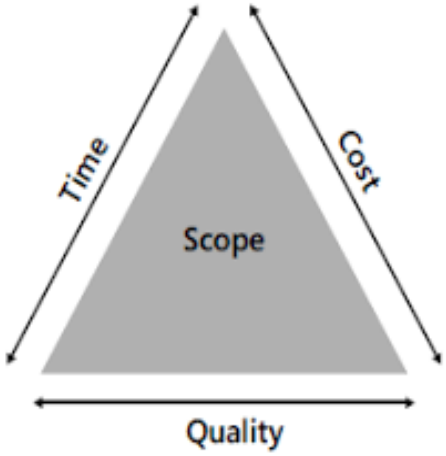

Figure 1: Project Constraints Triangle

It is argued that there are 7 different constraints for a project. The constraints are schedule, cost, resources, scope, quality, customer satisfaction, risk (RMC Publications, Inc., 2018). Heldman (2018), on the other hand, states that there are eight constraints on the projects that, time, schedule, budget, scope, quality, resource, technology and directives (Heldman, 2018). Additionally, Greene and Stellman (2019) argue that the constraints of project are scope, time, cost, quality, resource and risk. (Greene & Stellman, 2019)

1.5 Product Scope & Project Scope

Product scope is defined as the features, functions and properties that identify a product or service. Project scope is the total list of work packages which are required to complete the project successfully and meet the project goals with the specified features, functions and properties. Project scope must contain only the required tasks to get the job done; in contrast there can be two undesired results. First, scope creep which means demanded and realized results are not matched such as different features, missing properties etc., second is gold plating, which is defined as doing extra work by project team more than the initially requested requirements by the customer. (Project Management Institute (PMI), 2018)

1.6 Project Metrics

According to PMI PMBOK ® 6, there are three topics of metrics to measure the performance of a project. These are cost metrics, schedule metrics and quality metrics. Cost and schedule metrics are related to earned value management. Quality metrics are measured by various qualitative measurement techniques. (Project Management Institute (PMI), 2018)

1.6.1 Earned Value Management

It is argued in PMI PMBOK ® 6 that earned value management is a technique to view the performance of project's current status according to baselines of scope, cost and timeline. It has some parameters to identify the metrics and do calculations. (Project Management Institute (PMI), 2018) The parameters are;

Budget at Completion (BAC): BAC is the value of the total costs of the project completion at initial. There is no formula for BAC.

Planned Value (PV): PV is the value of estimations to complete the all work packages of project. Planned Value is calculated by the formula 1 below;

Formula 1: Planned Value

PV = BAC * Percentage of Planned Completion Rate

Earned Value (EV): EV is the value of how much of PV is actualized. Earned Value is calculated by the formula 2 below;

Formula 2: Earned Value

EV = BAC * Percentage of Actualized Completion Rate

Actual Cost (AC): AC is the value of how much is spent to have EV. There is no formula for AC.

Estimate at Completion (EAC): EAC is the value of the total costs of the project completion at now. EAC is calculated by the formula 3 below;

Formula 3: Estimated at Completion

EAC = AC+ (BAC – EV)

Estimate to Completion (ETC): ETC is the value of rest costs to complete the project at now. ETC is calculated by the formula 4 below;

Formula 4: Estimated to Completion

$$ETC = EAC - AC$$

Variance at Completion (VAC): VAC is the value of difference between forecasted cost and actual cost of project when it is completed. VAC is calculated by the formula 5 below;

Formula 5: Variance at Completion

$$VAC = BAC - EAC$$

To Complete Performance Index (TCPI): TCPI is the value of the required performance to complete project in budget. TCPI is calculated by the formula 6 below;

Formula 6: To Complete Performance Index

$$VAC = (BAC – EV) / (BAC – AC)$$

1.6.2 Schedule Metrics

According to PMI PMBOK ® 6, there are two analyses for schedule; the first is variance analysis and second is trend analysis. Schedule Variance (SV) is calculated by subtracting EV from PV with the formula 7 below;

Formula 7: Schedule Variance

$$SV = EV – PV$$

If SV = 0 that means project is on schedule, if SV > 0 that means project is ahead of schedule and in case of SV< 0 project is behind of schedule.

Schedule Performance Index (SPI) is calculated by dividing EV to PV with the formula 8 below;

Formula 8: Schedule Performance Index

$$SPI = EV / PV$$

If SPI = 1 that means project is on schedule, if SPI > 1 that means project is ahead of schedule and in case of SPI < 1 project is behind of schedule. (Project Management Institute (PMI), 2018)

1.6.3 Cost Metrics

It is expressed by PMI PMBOK ® 6that there are two analyses for costs, first is variance analysis and second one is trend analysis. Cost Variance (CV) is calculated by subtracting EV from AC with the formula 9 below;

Formula 9: Cost Variance

$$CV = EV - AC$$

If CV = 0 that means project is on budget, if CV > 0 that means project is under budget and in case of CV < 0 project is above budget.

Cost Performance Index (CPI) is calculated by dividing EV to AC with the formula 10 below;

Formula 10: Cost Performance Index

$$CPI = EV / AC$$

If CPI = 1 that means project is on schedule, if CPI > 1 that means project is under budget and in case of CPI < 1 project is above budget. (Project Management Institute (PMI), 2018)

1.6.4 Quality Metrics

PMI PMBOK ® 6 lists a number of tools for quality measurement. These are affinity schemas, flow charts, matrix diagrams, Ishikawa diagram (cause & effect diagram), histograms, Pareto charts and scatter diagrams.

- Affinity schemas are used to group the inconsistency reasons that have to be focused on.
- Flow charts are used to show the causes of result or defects in serial transactions.
- Matrix diagrams are charts, tables or summary tables which are used to provide analysis the complex relationships among current factors, causes and targets. It gives allowance to analysis and prioritization between plural issues.
- Ishikawa diagrams show a beneficial path to see and detect the root causes of problems.
- Histograms are used to make grouping and marking among errors with numbers and priority levels. Analysis and evaluation are made according to prioritization that is given according to density of frequency.
- Pareto charts are vertical stick chart which is beneficial to show the causes of problems with 80/20 rule. 80/20 rule means 80% of errors are came out by 20% percent of root causes.
- Scatter diagram are used to show how two different types of data have relationship each other (Project Management Institute (PMI), 2018).

2. PROJECT MANAGEMENT

2.1 Definition of Project Management

Project management is defined by Kerzner (2017) as a whole of planning, management, organizing and oversight activities for usage of resources, reducing costs and risks, maximizing the value while a project is executed for a business goal. (Kerzner, 2017)

It is argued by PMI in PMI PMBOK ® 6 that project management is the usage of properties that information, talents, tools, techniques for project works to provide successful result for project and meeting the criteria list of business demands. The project management is divided into 5 process groups which are initiating, planning, executing, monitoring and controlling, closing within 10 knowledge areas as project integration management, project scope management, project schedule management, project cost management, project quality management, project resource management, project communication management, project risk management, project procurement management, project stakeholder management (Project Management Institute (PMI), 2018).

2.2 Project Management Process Groups

2.2.1 Initiating

Initiating process group contains the starting official works, identifying the ground rules and checklists, detecting the working and environmental conditions which are going to be valid for project life cycle to create the official start document of project which is called as project charter. The initial registration of project stakeholders, who can affect the project or be affected by project outcomes, is completed at this process group and registration continues throughout the project life cycle at any time a new project stakeholder takes a position in the project. The project charter is official kick-off document of project and announces the information about the Project Stakeholders, initial limits, budget forecasts as roughly, time estimations, appointed and authorized project manager. The project charter becomes valid and official after it is signed by the sponsor of project (Project Management Institute (PMI), 2018).

2.2.2 Planning

Planning process group is the time interval for defining the project management plan that is a guideline about how to manage project during project lifecycle, and all the other project knowledge areas management plan about their specific procedures to declare how to be approached to the situations. Besides that, clarification the scope of the project, registration of the predicted risks for detected scope, preparation of baselines for cost and budget of the project transactions are completed at this process group (Project Management Institute (PMI), 2018).

2.2.3 Executing

Executing process group is formed the execution transactions of planned work items within the planned time and budget estimations while keeping quality at the expected level of project quality metrics which is detected by project quality management plan (Project Management Institute (PMI), 2018).

2.2.4 Monitoring and Controlling

Monitoring and controlling process group is the process that is performed permanently throughout project life cycle and the executed project work packages and tasks are monitored and approved by quality control to meet the quality expectations. In this process, the real performance of executed work list established and comparison of real performance results with planned performance metrics is completed. Result of that the differences are evaluated, and general status of project is put forward. In case of difference existence between real results and planned baselines, the updates on plans and baselines are performed in this process. So, risks are minimized, and correction steps are done for the projects (Project Management Institute (PMI), 2018).

2.2.5 Closing

Closing process group is formed by the closing actions, delivering outcomes, transferring last version of lessons learned onto the previous versions of the project. It is last step of project or phase of the project (Project Management Institute (PMI), 2018).

2.3 Project Management Knowledge Areas

According to PMI PMBOK ® 6 there are 10 knowledge areas with 47 tasks.

2.3.1 Project Integration Management

In that knowledge area, there are the tasks for keeping project as integrated and making all parts of the work items are correlated. These 7 tasks are creating project charter, preparing project management plan, directing and managing project work, managing project knowledge, monitor and control project work, performing integrated change control, closing project or phase (Project Management Institute (PMI), 2018).

2.3.2 Project Scope Management

This knowledge area consists of project scope works to plan, define, refine and manage the scope. The project scope tasks are 6 as planning scope management, gathering requirements, defining scope, creating work breakdown structure, validation of scope and controlling of scope (Project Management Institute (PMI), 2018).

2.3.3 Project Schedule Management

This knowledge area is used to create and get information about project time and schedule and to determine the status of project time-line and if any change in project which causes time change in project exists, update the plan and prepare the baseline again with its 6 tasks, planning schedule management, defining activities, sequencing activities, estimating activity durations, creating schedule and controlling schedule (Project Management Institute (PMI), 2018).

2.3.4 Project Cost Management

Project cost management is the knowledge area to use how to plan, manage, control and re-calculate costs and budget with the 4 tasks, which are planning cost management, estimating costs, determining budget, and controlling costs (Project Management Institute (PMI), 2018).

2.3.5 Project Quality Management

Project quality management is used to plan, manage and control quality in project with 3 tasks. The tasks are planning quality management, managing quality, and controlling quality (Project Management Institute (PMI), 2018).

2.3.6 Project Resource Management

Project resource management is the knowledge area that shows how to handle with the key production parameters of project, project team and resources. This knowledge area consists of 6 tasks, planning resource management, estimating activity resources, acquiring resources, developing team, managing team, and controlling resources (Project Management Institute (PMI), 2018).

2.3.7 Project Communication Management

Project communication management is the knowledge area about how to organize the communications during project life cycle with three tasks, planning communications management, managing communications and monitoring communications tasks (Project Management Institute (PMI), 2018).

2.3.8 Project Risk Management

Project risk management is the knowledge area about how to handle with risks of project with seven tasks, planning risk management, identifying risks, performing qualitative risk analysis, performing quantitative risk analysis, planning risk responses, implementation of risk Responses, and monitoring risks (Project Management Institute (PMI), 2018).

2.3.9 Project Procurement Management

Project procurement management is the knowledge area to manage procurements of project with three tasks, planning procurement management, conducting procurements and controlling procurements (Project Management Institute (PMI), 2018).

2.3.10 Project Stakeholder Management

Project stakeholder management is the knowledge area to manage stakeholders of project with 4 tasks, identifying stakeholder, planning stakeholder engagement, managing stakeholder engagement, and monitor stakeholder engagement. (Project Management Institute (PMI), 2018)

Knowledge areas matrix is depicted below in Table 3. (Project Management Institute (PMI), 2018)

Table 3: Project Management Knowledge Areas

Knowledge Areas	Process Groups				
	Initializing	**Planning**	**Executing**	**Monitor and Controlling**	**Closing**
Project Integration Management	Develop Project Charter	Develop Project Management Plan	Direct and Manage Project Work Manage Project Knowledge	Monitor and Control Project Work Perform Integrated Change Control	Close Project or Phase
Project Scope Management		Plan Scope Management Collect Requirements Define Scope Create WBS		Validate Scope Control Scope	
Project Schedule Management		Plan Schedule Management Define Activities Sequence Activities Estimate Activity Durations Develop Schedule		Control Schedule	
Project Cost Management		Plan Cost Management Estimate Costs Determine Budget		Control Costs	
Project Quality Management		Plan Quality Management	Manage Quality	Control Quality	
Project Resource Management		Plan Resource Management Estimate Activity Resources	Acquired Resources Develop Team Manage Team	Control Resources	
Project Communications Management		Plan Communications Management	Manage Communications	Monitor Communications	
Project Risk Management		Plan Risk Management Identify Risks Perform Qualitative Risk Analysis Perform Quantitative Risk Analysis Plan Risk Responses	Implement Risk Responses	Monitor Risks	
Project Procurement Management		Plan Procurement Management	Conduct Procurements	Control Procurements	
Project Stakeholder Management	Identify Stakeholders	Plan Stakeholder Engagement	Manage Stakeholder Engagements	Monitor Stakeholder Engagements	

2.4 Advantages of Project Management

It is argued that project management is used to have a more controllable process, do better evaluation and provide higher quality in deliveries. As a result of these advantages project management provides ensuring good relationship with stakeholders, especially customers, having nice work climate in organization, reducing costs and risks and successful projects. (Project Management Institute (PMI), 2018)

Albayrak (2011) asserts that utilization of project management techniques leads to the benefits listed below;

- Determines the target at the beginning
- Defines the roles and rules
- Provides high quality and stakeholder satisfaction
- Sharps the talents of project team
- Good control processes
- Better customer relationships
- More economical production
- Efficient resource usage
- Less cost and highly marge profit
- Detects the required resources
- Determination of required time and cost at the beginning
- Defines the technology or procedures to do the work (Albayrak, 2011)

2.5 Disadvantages of Project Management

There are some disadvantages of project management application. These disadvantages are asserted by Butler Jr (1973) below;

- Complexity in organization structure
- Difficulties in management
- Tendency to corrupt the organizational policies
- Difficulties in staff usage (Butler Jr., 1973)

2.6 Program Management

A program is formed by related projects and sub-projects and their related works. Program management aims to maximize the value and success possibility of projects that have dependencies on each other and minimize the risks that can be occurred if management coordination is missing. If there are interrelated projects or related works, an organization can manage them within a program approach to get the highest return. (Project Management Institute (PMI), 2018)

Program Management structure is shown in the Figure 2 below.

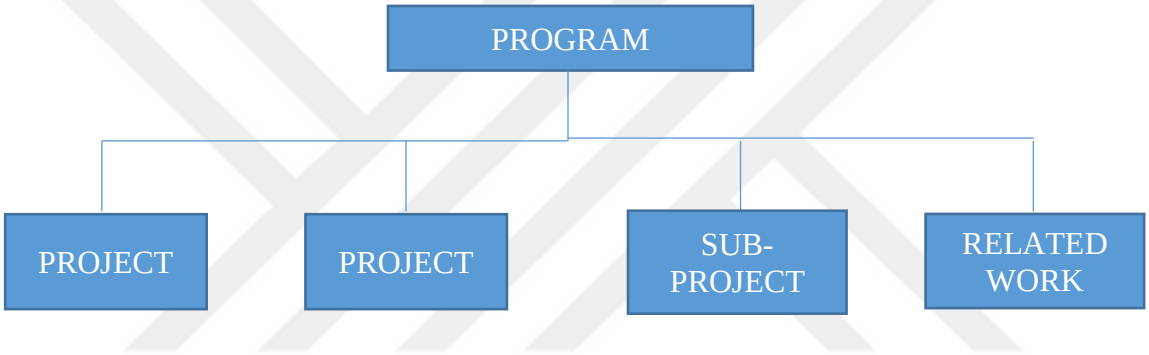

Figure 2: Program Management

2.7 Portfolio Management

A portfolio is combined by programs, dependent or independent projects, and operational works. Portfolio management is created to administer all works by portfolio management department which are aiming to maximize the yield of organizational business target. The main role of portfolio management in organizations includes obtaining the optimum resource usage, decreasing level of risks for organizational strategy compatibility rather than managing each work topic individually, and achieving to earn the most possible utility from all the works of organizations which are related or unrelated each other. (RMC Publications, Inc., 2018)

Portfolio management structure is shown in Figure 3 below;

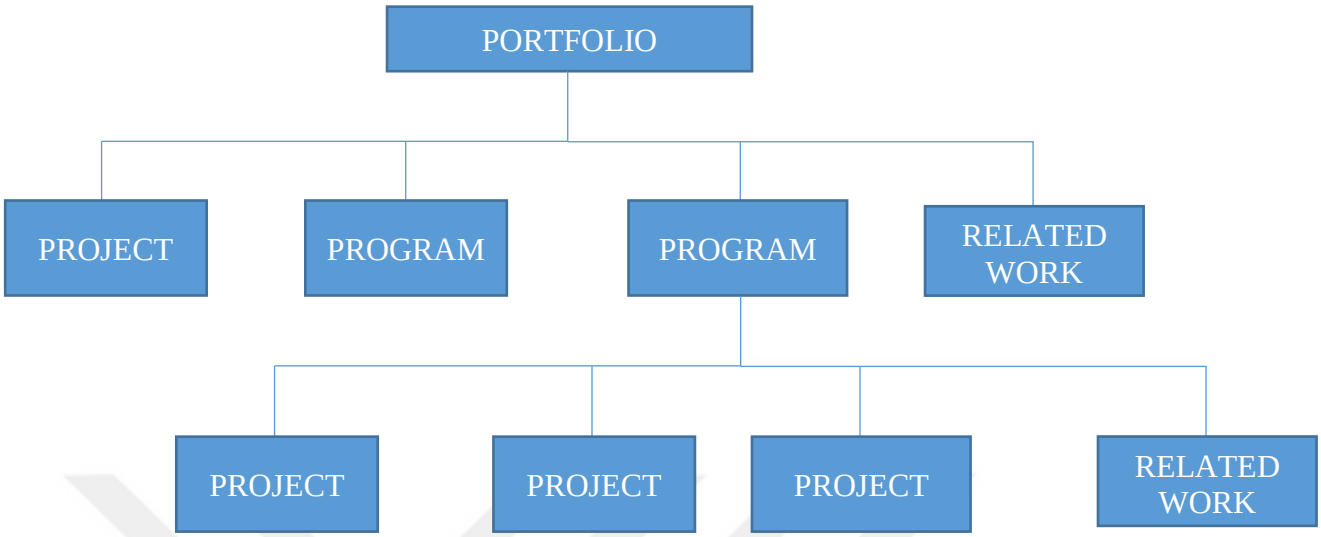

Figure 3: Portfolio Management

3. PROJECT MANAGEMENT METHODOLOGIES

Project management methodology is defined by Cockburn (2000) as the kind of principle which provides delivery with successful result. Cockburn argues that there is not a single methodology that has a chance to be appropriate for all project types. (Cockburn, 2000) Charvat (2003) defines project management methodology as a set of principles and rules that are customized according to different conditions and are applied differently in projects. (Charvat, 2003)

The current project management methodologies are categorized by Spudnak (2014) as traditional methodologies and agile methodologies. The waterfall methodology has been argued by Spudnak (2014) as being rational, and loyal to the settled rules of project with detailed planning and not letting too many or too big changes that directly affect the plans of project. But with the continuous improvements in all sectors and pushing the project limits of restrictions downward during the project are the reasons behind formation of a new project management methodology: "agile". These two different methodologies have their positive and negative sides in different cases and according to project and organizational structure. Thus, the selection of most compatible methodology is a critical factor for bringing the project to success. (Spudnak, 2014)

As mentioned in PMI PMBOK ® 6, there are two main project management methodologies which can be used in projects: (1) waterfall, and (2) agile (Project Management Institute (PMI), 2018).

3.1 Waterfall Project Management Methodology

3.1.1 Definition of Waterfall Project Management Methodology

Gencer and Kayacan (2017) define waterfall as a methodology or approach for project management in various sectoral projects. Waterfall methodology is also known as the traditional project management methodology. In waterfall methodology, the processes are sequenced, the project proceeds step by step between distinct stages and all required work must be completed before moving to the next step. Prior to this methodology, the "code and edit" principle was used in software area. However, due to increasing demand to software and huge software crisis at the end of 1960s, a rule set and guide for software project management was required to meet the

requirements. These principles were based on Fayol's 14 principles of management and the principles defined by Winston Royce in 1970 (Gencer & Kayacan, 2017). It is argued that the term "waterfall" was not mentioned by Winston Royce in his definition, but because of the structure this name was called anonymously. Waterfall should be applied where the requirements are defined well, documented with deep details (Despa, 2014). Royce (1970) listed the steps of waterfall as: collecting requirements and documentation, analysis, design, coding, testing and operations. There could be going backs in case of error or missing existence, but with accurate scope determination and detailed documentation, the risk of error occurrences has been aimed to be prevented (Royce, 1970).

Waterfall methodology steps are shown in Figure 4 below.

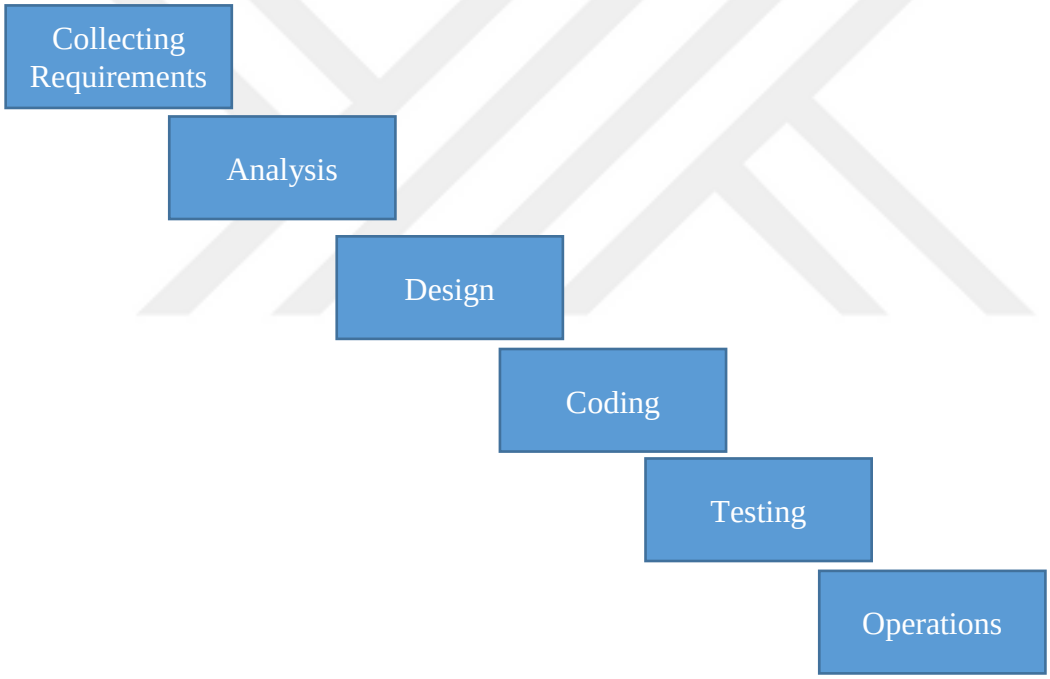

Figure 4: Waterfall Methodology

3.1.2 Advantages of Waterfall Project Management Methodology

Gencer and Kayacan (2017) list the advantages of waterfall as:

- More accurate forecasts for budget and schedule with clear and exact requirements
- It is a well-known method due to wide-spread utilization
- Rules and roles are defined well, so it is ideal for inexperienced project members
- Controlling is simple since completion of a project stage is required before moving to the next stage

- High-qualified documentation
- Change management is easy with detailed scope
- Prevents overloading of personnel with defined timelines

Additonally, Balaji and Murugaiyan (2012) list advantages of the waterfall methodology as;

- Requirements are defined and documented before development
- The time interval is forecasted and determined for each stage
- It is easy to execute
- Less resources are needed
- High quality is produced with well documentation

(Balaji & Murugaiyan, 2012)

Despa (2014) expresses the waterfall method advantages as;

- Project team can easily sense the core of the project
- Management and execution of steps are easier because of being kept as separate stages
- Provides an easy management environment for project managers

(Despa, 2014)

3.1.3 Disadvantages of Waterfall Project Management Methodology

Gencer and Kayacan (2017) argue that the disadvantages of waterfall are,

- Because of getting back to previous steps it causes high correction costs of failures
- Restricts changing elasticity and increases costs and postpones time
- Undetected defects negatively affect all other steps
- Because of its structure, waterfall is slow, cumbersome and not flexible
- Any lack of requirements can only be detected at design and coding steps
- Performance cannot be measured till the end of coding step
- Because of its high discipline level, it reduces creativity
- High management costs
- Has shortcomings about responding to later possible requirements
- Documentation takes long time
- A delay in previous steps directly delays subsequent steps

- Because completing delivery at the end of the project or phase customer expectation meeting ratio is low

  (Gencer & Kayacan, 2017)

  The disadvantages of waterfall are expressed by Balaji and Murugaiyan (2012) as;

- In case of client requirement change, it cannot be applied
- It causes long period for delivery
- If any problems which is raised at any step are not solved before ending of a step, it corrupts all subsequent steps

  (Balaji & Murugaiyan, 2012)

  The disadvantages of waterfall are expressed by Melinmani (2017) as;

- Small changes can be the reason of drastic changes
- Not flexible
- It is difficult to control the status of steps
- Risk level is high

  (Melinmani, 2017)

  Despa (2014) argues the disadvantages of waterfall as;

- Has problems to cover the requirements changing
- Not flexible for design and analysis errors (Despa, 2014)

3.2 Agile Project Management Methodology

3.2.1 Definition of Agile Project Management Methodology

Beck et al. (2001) stated that the agile project management methodology was firstly introduced as agile manifesto with its concepts. It has been created by experienced software professionals. However, due to its iterative structure, it is used in a variety of sectors today. Agile manifesto was created to find out more suitable ways to develop and support software under four guiding principles. These principles are:

1. people and their communication are more important than processes and tools,
2. a working code is more beneficial than complex documentation,
3. customer cooperation is more valuable than agreement debates, and
4. adapting to variation is more needed than following the plan.

It is declared in agile manifesto that the following twelve values will ensure realization of the above four principles. These values are;

a. The most important criterion is making customers happy with delivering valuable software as soon as possible and frequently
b. Adapting changes at each step of development. Agile processes consider change as a positive benefit of customer.
c. Delivery of working software in a short period such as weeks or months.
d. People who are from business side and development teams have to work with high level of collaboration and on a daily basis.
e. Keep the motivation of project team at the top, give their needs to work and support whenever they want, and trust the team to complete the work.
f. The top point of effectiveness in information transfer is face to face communication method.
g. Set the working software as the key metric of advancement
h. Agile processes provide sustainable environment and execution. All stakeholders should be able to keep constant progress.
i. Agility increases with incessant technical perfection and fine design
j. Simplicity is the key
k. The best works such as architectures, requirements and designs are created by self-organized teams.
l. Teams should adapt their attitudes to be more precious periodically.

(Beck, et al., 2001)

Hoda et al. (2008) declared that agile methodology has an iterative and incremental development style which provides rapidly regulation to the modification on demands and facilitates management of risks (Hoda, Noble, & Marshall, 2008).

Fair (2012) argues that agile is an approach for project management which arises from lean thinking. It promotes some basic rules such as controlling and modifying often, increasing team relations, self-organizing and transparency, high-qualified and fast delivery of products, meeting customer expectations and targets. Agile is based on empiricism, prioritization, and self-organizing, time-boxed, collaboration (Fair, 2012).

Fernandez and Fernandez (2009) stated that with the increasing pressures due to globalization, a project manager has to deal with more uncertainty. The strategies which are effective in dealing with uncertainty are listed as linear, iterative, extreme, incremental and adaptive strategies. Linear strategy is the most similar to waterfall in scope where design, building, testing and delivery follow each other respectively. In incremental strategy, there is a coming back to the building process after deployment and the defects of production are fixed after deployment. In the iterative strategy, after the testing process there is a control process called UAT (User acceptance tests) to check whether there is a need to go back to the building step and it is repeated after deployment. In adaptive strategy, the check process is completed after design and makes it again after deployment, in extreme control phase is done after scope process and repeated after deployment (Fernandez & Fernandez, 2009).

According to Rasnacis and Berzisa (2016), all the agile methodologies (such as scrum, kanban, lean software development, extreme programming, dynamic systems development method, and feature-driven development) have disciplines and rule sets on project manager, project life cycle, project team and product delivery. And these owning disciplines and rule sets are iterative to implement them on the same basis. Mostly followed and important rule set is team management for agile. To guarantee the success of a project, team relations should be improved as much as possible and then the other factors could be developed such as organization, process, and technical facilities (Rasnacis & Berzsia, 2016).

Coram and Bohner (2005) state that there are three different sub-dimensions of agile methodology. “Xp” is the most disciplined and commonly principled way of agile to apply five basic steps, and “scrum” is the most appropriate way to adapt to changes during project with elasticity and dynamic system development method which has constant time and sources to do a correct feasibility and plans the prepare of the practicality with increasing axis (Coram & Bohner, 2005). It is stated by Coram and Bohner (2005) that these three sub-dimensions are coming together with four principles in agile manifesto: (1) giving importance to staff and their communication more than process and instruments, (2) spending big percentage of time on code writing rather than to prepare documentation, (3) development of stakeholder cooperation, and (4) in case of change, responding to it as fast as you can. And then, the effects on project staff are decreasing the load of the project team, integration of each stakeholder to the project target, more

clearly and easily controllable process of production for project manager and customer (Coram & Bohner, 2005)

Gencer and Kayacan (2017) says xp, scrum, crystal methodology, kanban, dynamic system development method, adaptative software development, feature driven development are types of agile methodology practices. They also state that agile method as an iterative and having tendency to continuous improvement methodology in self-sufficient teams. (Gencer & Kayacan, 2017)

90% of teams who applied agile practices use the scrum in their operations, kanban is second with 4% and xp is third with %2.5 (Forrester Research Inc., 2013).It is emphasized by Scrum Alliance Inc. that 94% of agile methodology appliers are using scrum methodology in their operations (ScrumAlliance Inc., 2019). According to 13th Annual State of Agile Report, scrum is the leader with 54% on application among agile methodology user companies (Version One Inc, 2019). It is argued by Agile Turkey in 7th Annual Agility Report that the mostly used agile approach is scrum with 92% and not being agile applications users in processes is only 6% among report respondents (Agile Turkey, 2017).

3.2.2 Types of Agile Methodology

3.2.2.1 Scrum

According to Schwaber and Sutherland (2017), who are the creators of the scrum guide, the scrum is a carcass to be used by people to discuss and solve the complex modifying difficulties while producing products with the most enormous degree for customers (Schwaber & Sutherland, 2017)**.**

Schwaber and Sutherland (2017) define the scrum as simple, easily understood, and hard to be experienced. They argued that scrum is based on empiricism with three milestones: transparency, inspection and adaptation. Scrum has five values that are commitment, courage, focus, openness and respect. Scrum is conducted by a scrum team with three different roles: development team, scrum master, and product owner. A person can take more than one role in a team but, there cannot be more than one product owner for one product. And the development team which is comprised by 3 or 9 people must have the capabilities to get all the clarified work done without and dependency to others. Scrum has “sprints” which are defined as time intervals to complete the part of work and there is a sprint work list which is called as “the sprint backlog”.

And all the work items are listed under product backlog which exists while the product exists. The sprints have four official meeting types which are sprint planning, daily scrum, sprint review and sprint retrospective. The scrum team plans which work packages are going to be involved to next sprint in sprint planning, whereas the development team members update the status of actual work list of sprint and provide transparency. The scrum team controls the previous sprint works and finalizes their last status at sprint review. At the sprint retrospective meeting the scrum team discusses the status, evaluates trend of team with positive and negative parts and tries to find out how to provide elimination on their shortcomings (Schwaber & Sutherland, 2017).

3.2.2.2 Kanban

Kanban means “signboard” in Japanese, and is a visual philosophy to implement agile. It focuses on changing and improving the current systems with continuous and incremental changes. It is based on visualization of the orders and items of the workflow, limiting the actual work with current capacity, being just-in-time, controlling and expanding the flow, clarification procedures, and continuous improvement (Kumar & Pannerselvam, 2006).

3.2.2.3 Extreme Programming

Extreme programming (xp) is defined by Lindstrom and Jeffries (2004) as a software development discipline which is focused on plainness, communication, feedback and bravery. The members are formed by customers who are at the center of the team, business representatives, developers, testers and they are called as whole team. The xp team members work all together in all operations such as pair programming, with providing effective communication to each other to provide transparency on showing project status in the light of simple and basic practices in xp (Lindstrom & Jeffries, 2004).

3.2.2.4 Adaptive Software Development

Highsmith (1999) states that the adaptive software development is a philosophy which argues always being in a continuous adaptation process of projects. Adaptive software development has three cycles for production: speculation, cooperation and learning, which are continuously consecutive (Highsmith, 1999).

Highsmith (1999) proposes that there are five key targets of asd, which are;

a. Providing an alternative to the perception that optimization is the unique solution for more complex issues.
b. Provide a set of frameworks or models to an organization in the usage of adaptable principles.
c. Create a cooperation and interaction between the people who have alike or not alike attentions to find solutions of organizations in emergent product development problems
d. Identify a procedure for organizations to use the adaptive approach in their large-scale projects
e. Recommend an effective management manner for organizations (Highsmith, 1999)

3.2.2.5 Feature Driven Development

According to De Luca (2017) who is the creator of feature driven development (fdd), fdd is a development process which is focused on delivery of the working and valuable software as iterative and incremental. It focuses the client needs first, so the producers care the requirements and features which are demanded with prioritization by customer. There are five processes of fdd;

a. Forming a general model
b. Preparing the list of features
c. Doing the plan according to feature
d. Completion of design according to feature
e. Development according to feature

(De Luca, 2017)

3.2.2.6 Lean Software Development

Poppendieck and Poppendieck (2003) argued that, the lean software development (lsd) is application of lean procedures of manufacturing with lean thinking on software development area. Lsd provides a decent framework for organizations with its values and rules that are shaped by experienced practices and that support agility. There are seven rules for lsd;

a. Remove waste
b. Increase learning
c. Take decisions as late as possible
d. Do delivery as early as possible

e. Strengthen the team
f. Provide integration
g. Optimize the all of it (Poppendieck & Poppendieck, 2003)

3.2.2.7 Dynamic Software Development

Moran (2015) argues that dynamic systems development method (dsdm) is a software development methodology which is based from agile framework. The dsdm has properties as being iterative and incremental, and contains the rules of agile development such as constant customer participation like all other agile methodologies. It has eight principles in application;

a. Focusing on the needs
b. Delivery on time
c. Cooperation
d. Don't letting quality loss
e. Iteratively development
f. High effectiveness in communications
g. Showing control
h. Building up step by step from the basement of organization (Moran, 2015)

3.2.3 Advantages of Agile Project Management Methodology

Gencer and Kayacan (2017) say the benefits of this method are below;

- Ensures progress in unspecified project scopes
- Being compatible to changes on project,
- Highly performed communications in short time,
- Continuous improvement and iterative delivery on outcomes,
- Less documentation time for the team and focusing on the core of the business. (Gencer & Kayacan, 2017)

Cockburn and Highsmith (2001) argue the advantages of agile as;

- Focuses on client, and makes clients are involved to whole process constantly
- Because of used by self-organized team, motivation is high
- Assures quality

- Transparency is high, so each stakeholder knows the progress status of project.

(Cockborn & Highsmith, 2001)

Fair (2012) tells the advantages of agile applications as;

- Being flexible to change constantly
- Cross-functionality which assures a team has enough capabilities to get the work done
- Transparency is high, so each stakeholder knows the progress status of project.
- Simultaneous collaboration decreases dependency among stakeholders
- Short planning time consumption with iterations
- High face to face communication with customer to understand requirements

(Fair, 2012)

Despa (2014) defines the advantages of agile as;

- Frequently delivery of outcomes,
- Easy orientation to changes
- Getting early notification for process or outcome from customer

(Despa, 2014)

3.2.4 Disadvantages of Agile Project Management Methodology

Gencer and Kayacan (2017) list the disadvantages of agile as;

- Resource and scope planning are hard because its change welcoming approach
- Hardness to implement on corporate companies
- Project success easily affected by the involvement of customers
- Less documentation
- Less experienced team members can cause to decrease in team performance
- Priority changing

(Gencer & Kayacan, 2017)

According to Despa the disadvantages of agile are;

- Risks in documentation missing
- Less chance to be successful with inexperienced team members
- Estimation conflicts in complex projects

(Despa, 2014)

Balaji and Murugaiyan (2012) define the disadvantages of agile as;

- Implementation difficulties on large scale projects
- Hardness to being experienced of non-experienced members without experienced team members

(Balaji & Murugaiyan, 2012)

3.3 Project Success Status and Comparison of Agile and Waterfall Methodologies

Montequin et al. (2016) have argued that there are certain reasons behind the success or failure of a project. The reasons for why a project fails are ravage of competitors, big or constant changes on requirements, not defined or not correct requirements, disagreements between stakeholders, wrong cost estimations, wrong time estimations, shortcomings on procurements and their management, lack of board support, missing of legal information, political-social-economic or legal changes, wrong defined features, insufficiency of project manager on commitment-communication-competence, vision, missing documentation, staff allocation changes, shortcomings on required competence, misunderstanding of requirements or business needs, project team shortcomings on commitment, resistance by public, insufficient quality, having extremely complicated technology, unexpected results or events, Inconsistency and irrationality on customer demands, wrong number of staff. The factors for a project to be successful can be listed as acceptance of change, well-defined vision and targets, well-defined, exact project requirements, controlling of schedule, quality and budget, involvement of stakeholders, less bureaucracy, support of board, good financial conditions or guarantee, showing good project management skills on commitment-communication, rational and true goals and expectations, accurate estimations on cost and time, correct number of staff, project team commitment and competence, well and often communication (Montequin, Cousillas, Alvarez, & Villanueva, 2016).

Ionel (2008) stated that the parameters of decision making to use agile methodology in software projects rather than waterfall are customer demands, time restrictions, competition with rivals, ensuring the quality, high resources experience, foresight of uncertainty (Ionel, 2008).

Griffin and Roldan (2013) compared waterfall and agile project management methodologies according to parameters of project management life cycle. They are argued that idea generation is same for both of them as prepared at the start of project and declares the requirements of

customers. The proposal is formed at the start of project after business need declaration in waterfall; whereas in agile it is formed again at each phase. Charter is prepared for waterfall, in agile it is together with proposal. In waterfall, business requirements are formed, in agile product backlog is formed. Waterfall has a project definition document that contains the plans of five process groups; this is not applied in agile. In waterfall, project plan is detailed and well-defined to provide facility for milestones, but in agile it is done with sprint and product backlogs. In waterfall there is an additional communication plan to manage the communication process is going to be during project, whereas in agile with effective and time independent communication channels, this plan is not needed. In agile product backlog is prepared as a detailed list of requirements, because of detailed business requirements already defined at the beginning, this is not needed in waterfall. In agile, sprint backlog is used to monitor the detected timeline, whereas in waterfall, project plan is used to follow the project status. In agile there is an instrument called "burn down chart" to check the daily status of sprint, but that is not used by waterfall methodology. The lessons learned which increase the maturity of the project resources are prepared at the end of each detected short time period called as sprint in agile, in waterfall all the lessons learned are formed at the end of the project. The lessons learned can be insights for the other conflicts in same project or another projects in the company. (Griffin & Roldan, 2013)

Agile project management applications of highly complex software projects are considerably beneficial to increase the schedule performance index and to decrease the detected bug numbers in similar magnitude of scopes rather than waterfall methodology applications (Project, M. J., 2013).

It is stated by Chowdhury (2018) that if the expectations of outcomes are clear in the mind of the customer and all the necessities are well-defined, the project manager should choose waterfall methodology to apply in the project. But if there are misunderstandings or missing points of the requirements and if proper delivery of product or service which is stated as outcome of project is planned by customer, to cover the customer needs and adapting to the changes in the project life cycle agile methodology is compatible to use (Chowdhury, 2018).

It is stated by Suetin et al. (2016) that even though there are opposites, the results show us agile project management applications in software projects cause negative effects on cost and time areas. On the other hand, for all stakeholders (project team, customers and others) the meeting quality requirements ratio is increased dramatically when agile project management

methodology is applied at the projects. (Suetin, Vikhodtseva, Nikitin, Lyalin, & Brikoshina, 2016)

It is declared by Mitchell and Seaman (2009) that more effort is required in agile projects than in waterfall projects. Agile projects need fewer efforts in collecting requirements but spend more effort in test phase than amount of waterfall projects' test phase. Developers are enabled to be at high productivity when they take a part of agile projects rather than waterfall. The correctness of estimations for cost and schedule are higher in agile projects than waterfall and it has higher possibility to have more qualified products or results when agile projects are executed rather than waterfall (Mitchell & Seaman, 2009).

It is argued by Standish Group Inc. (2015) the "CHAOS Report" is a research project that based on informational technologies projects, for results and best practices of project management methodology. During the research measures success ratios of software projects in various sectors with criterion. The criterion of "CHAOS Report" for being successful in a software project are providing being on time or in front of time, being on budget or under budget and on scope with meeting the quality requirements. (Standish Group Inc, 2015)

The factors of project success are shown in Table 4 below (Standish Group Inc, 2015);

Table 4: CHAOS Factors of Success

Success Factor	**Effect on Project Success (%)**
Support of Upper Management	15
Customer/User Involvement	15
Project Optimization	15
Emotional Maturity	15
Competency of Project Staff	10
Standardization on Procedures	8
Agility on Processes	7
Simple Management	6
Project Manager Competency	5
Well Defined Targets	4

Project success rates are shown in Table 5 below (Standish Group Inc, 2015);

Table 5: CHAOS Project Success Rates from 2011 to 2015

	2011	**2012**	**2013**	**2014**	**2015**
Successful	29%	27%	31%	28%	29%
Challenged	49%	57%	50%	55%	52%
Unsuccessful	22%	16%	19%	17%	19%

Project success rates according to the methodology implemented are shown in Table 6 below (Standish Group Inc, 2015);

Table 6: CHAOS Project Success Rates According to the Methodology Implemented

	Waterfall	**Agile**
Successful	11%	39%
Challenged	60%	52%
Unsuccessful	29%	9%

It is declared by Standish Group in their report the result ratios of projects, according to methodology are shown in table 7 below (Standish Group Inc, 2015);

Table 7: CHAOS Project Success Rates According to Size and the Methodology Implemented

Size	**Methodology**	**Successful**	**Challenged**	**Unsuccessful**
Big	Agile	18%	59%	23%
	Waterfall	3%	55%	42%
Medium	Agile	27%	62%	11%
	Waterfall	7%	68%	25%
Small	Agile	58%	38%	4%
	Waterfall	44%	45%	11%

4. SOFTWARE

4.1 General Information about Software

4.1.1 Definition of Software

Software is defined as computer programs, procedures, rules and associated documentation of an information processing system (IEEE, 2010). According to Cambridge Dictionary, software means “the instructions that control what a computer does; computer programs” (Cambrdige Dictionary, 2019).

Turkish Language Association (TDK) defines software as all programs, procedures, programming languages and documentation used in computing to bring hardware to life on a computer (TDK, 2019). Software is argued as a theory by Alan Turing in his article “Computable numbers with an application to the Entscheidungsproblem” about solving the complex and unknown problem systematically (Turing, 1935). Tukey (1958) was the first user of the term “software” in his article (Tukey, 1958). Sommerville (2016) describes software as computer programs with documentation which is guide for prepared programs. The software can be produced for private customer or for public usage. Software can be divided into three main groups. These are;

- System Software: The software which operates as working platform for productive or application software. System software examples operation systems, hardware coding programs etc.
- Programming Software: The software that tools or programs for programmers to write their own or commercial programs.
- Application Software: The software that programmed by programmers for consumers in their works, operations, usages and daily activities. (Sommerville, 2016)

4.1.2 Definition of Software Engineering

Sommerville (2016) defines software engineering as the engineering discipline and procedures which are formed by the activities in each stage of software production from the beginning as system description to the end as usage by costumers and maintenance of software.

These activities are called “software development life cycle (SDLC)”. Software engineering contains the technical part of the software development process, the methodology or approach for software development, software project management tools and methods which are useful to convey the software projects and software production that finalizing the software according to requirements in its scope (Sommerville, 2016)**.**

Sommerville (2016) argues that there is an increasing need to software products for society and that need should be met in the way of accurate, reliable, quick and economical. In the long-term using software engineering makes the production clearer, more effective and cheaper than coding programs only. So, these are showing importance of software engineering. At the step of software production there is a systematic approach for all software engineering activities which are called as software process. The activities are;

- Software specification: It is the step of the definition that done by engineers and customers about the software to be produced with its constraints and operational functionality.
- Software development: It is the step of design and execution of defined software.
- Software validation: It is the step of verifying whether the produced software meets the requirements.
- Software evolution: It is the step of modification the produced software according to changed or newly emergent requirements from customers or market. (Sommerville, 2016)

To define the software engineering and its scope Software Engineering Body of Knowledge (SWEBOK) is prepared by IEEE. In 2014 3rd Edition of SWEBOK was published by IEEE. At this book the purposes of generation are explained as;

- Providing a common point for software engineering around the world
- Definition the scope of software engineering and detect its place among the relevant disciplines. The relevant disciplines are computer science, project management, computer engineering, and mathematics.
- Explaining what software engineering discipline contains
- Giving public access to the software engineering body of knowledge in the base of subject

- Preparing a baseline for teaching programs, certifications and licensing activities (IEEE, 2014)

In the preparation of SWEBOK V3, 15 knowledge areas have been defined by IEEE. These are;

- Software Requirements: Declares how to gather the requirements, their analysis, identification, verification and management of them during SDLC.
- Software Design: Defines the internal structure, architecture, components, interfaces and other properties of to be produced software according to analysis of requirements.
- Software Construction: Preparing of demanded software with writing code, debugging, validation, unit testing, and integration.
- Software Testing: The step of validation the produced software according to requirements.
- Software Maintenance: Refers solving the problems which are emergent on production and adding changes to working software.
- Software Configuration Management: Configuration of software according to requirements with project management, development and maintenance, quality assurance.
- Software Engineering Management: The management activities of software engineering that contain planning, coordination, measurement, viewing, controlling and reporting to make the software products or services efficient, effective and useful for customers.
- Software Engineering Process: The requirements relate to activities performed by software engineers for the purpose of developing, operating and maintaining software such as design, creation, testing.
- Software Engineering Models and Methods: Aims to provide a structure to software engineering with making the structure systematic, repeatable and successful-oriented.
- Software Quality: The meeting ratio of requirements by produced software under certain circumstances.

- Software Engineering Professional Practice: The required knowledge, skills and attitudes to perform the software engineering with responsibility, professionally and ethically.
- Software Engineering Economics: Contains the business management and decisions to make the product or service in business context.
- Computing Foundations: Includes the development and operational environment where the software maturated and conducted.
- Mathematical Foundations: While the logic that defines how the software behaves, is transferring in programming code; it helps the software engineers to understand the logic completely.
- Engineering Foundations: Engineering is defined as systematic, disciplined and measurable attitude to products, services, structures, machines, processes or systems.

  (IEEE, 2014)

It is identified in SWEBOK V3 that there are seven different disciplines with software engineering. These disciplines are;

- Computer engineering
- Computer science
- General management
- Mathematics
- Project management
- Quality management
- Systems engineering (IEEE, 2014)

4.2 Software Usage Areas

The total magnitude of the technology industry is going to be $5 trillion at the end of 2019 via 4% annual increase. Additionally, the number of personnel employed in information technology area is forecasted to be 50 million people (CompTIA, 2019).

There is no sector which has no interaction with software industry. But, especially artificial intelligence, cloud, telecommunications, internet of things are the leaders for software consumption (CompTIA, 2019).

With regards to industry-specific software applications, there are 47 industries which have at least one software produced for their operations. The sectors with the most applications are education, finance, travel, construction, restaurant management, logistics, healthcare, fitness & health, volunteering, retail, manufacturing, electronics, and food & beverage (crozdesk.com, 2019).

Industries that use software most are social networking, games, entertainment, business, education, media, telecommunication, sports, shopping, and finance (apptrace.com, 2019).
Industries that are researched for software projects are banking, financial, government, healthcare, manufacturing, and retail, services, telecom and others (Standish Group Inc, 2015).

4.3 Software Projects

4.3.1 Status of Software Projects

It is argued by Standish Group in CHAOS Report the general status of software projects according to project size is shown the table 8 and table 9 below (Standish Group Inc, 2015);

Table 8: CHAOS Resolution by Project Size

Project Size	Successful (%)	Challenged (%)	Failed (%)
Grand	2	7	17
Big	6	17	24
Medium	9	27	31
Moderate	21	32	17
Small	62	17	11
Total	100	100	100

Table 9: Project Size by CHAOS Resolution

Project Size	Successful (%)	Challenged (%)	Failed (%)	Total (%)
Grand	6	51	43	100
Big	11	59	39	100
Medium	12	62	26	100
Moderate	24	64	12	100
Small	61	32	7	100

4.3.2 Problems of Software Projects

Problems related to software projects can be categorized into three main groups:

People-related problems:

- Managing and motivating project members inadequately
- Providing shortcomings of the tools and techniques to project members which are required to produce outcomes

Process-related problems: Not defining the correct responsible of results

- Having inconsistent process to handle with unclear controlling criteria list
- Not having reliable approach for planning and conducting projects

Communication-related problems:

- Concentration on wrong sides, technical details rather than value of project
- Not involving of customers constantly to the project (Discenza & Forman, 2007)

Reasons behind project failures can be listed as:

- Having unambiguous and not finalized requirements
- User involvement shortcomings
- Resource inadequacy and technical knowledge lack
- Wrong or inconsistent expectations
- Planning mistakes or shortcomings
- Shortcomings on information technology management
- Not supported by board
- Continuously changing scope
- Being the project unneeded (Frese & Sauter, 2003)

5. RESEARCH METHODOLOGY

5.1 Research Hypotheses

Project management methodology is defined by Cockburn and Highsmith (2001) as the kind of principle which provides delivery with successful result. They argue that one methodology does not have a chance to be appropriate for all projects (Cockborn & Highsmith, 2001). It is argued that project management can be used to have a more controllable process, to do better evaluation and to provide higher quality in deliveries. Therefore, project management provides building good relationships with stakeholders, especially customers, having nice work climate in organizations, reducing costs and risks, and ensuring successful projects. (Project Management Institute (PMI), 2018)

The main objective of this study is to compare waterfall and agile project management methodologies with regards to performance metrics of project cost, project time and project quality. Various sources from literature were reviewed to arrive at the hypotheses of the study. It has been reported that the success ratio of agile methodology is 3.5 times higher than that of waterfall methodology. The success rate reaches up to seven times bigger depending on the size of the project (Standish Group Inc, 2015).

Project costs have strong relationships with chosen project management methodology (Spudnak, 2014). Fernandez and Fernandez (2009) emphasized that budget performance of a project depends heavily on the chosen project management methodology. It is also argued that project budget is closely related to project management methodology (Cockburn, 2000). Gencer and Kayacan (2017) argued that agile project management methodology is better to meet the cost metrics on projects (Gencer & Kayacan, 2017).

In line with the comments above, the following hypothesis is constructed:

H1: There is a significant difference between cost performance of waterfall and agile projects.

Gencer and Kayacan (2017) argued that the delivery time of a project is related to the chosen project management methodology, and that agile is more effective than waterfall in providing the project time metrics (Gencer & Kayacan, 2017). Fair (2012) stated that the project

time plan and success in meeting milestones for deliveries is affected by the project management methodology (Fair, 2012). Balaji and Murugaiyan (2012) also state that usage of project management methodology is the critical for time, and add that waterfall has disadvantages to reduce the delivery time (Balaji & Murugaiyan, 2012).

According to the findings above, the following hypothesis is formed:

H2: There is a significant difference between time performance of waterfall and agile projects.

Balaji and Murugaiyan (2012) argued that project management methodology provides quality for activities, and added that quality metrics are met with chosen project management methodology (Balaji & Murugaiyan, 2012). Ionel (2008) stated that the parameters which are the causes of to use agile methodology in software projects rather than waterfall as customer demands, time restrictions, challenging with rivals, ensuring the quality, high resources experience, foresight of uncertainty occurring. (Ionel, 2008) It is also emphasized by Suetin et al.(2016) that quality metrics are related to chosen project management methodology. (Suetin, Vikhodtseva, Nikitin, Lyalin, & Brikoshina, 2016). Therefore it is hypothesized that:

H3: There is a significant difference between quality performance of waterfall and agile projects.

5.2 Sampling

A non-probability sampling method was used in this study to determine the sample of the research (Gegez, 2019). Both convenience and snowball sampling techniques were utilized. Gegez (2019) states that a convenience sample entails including just accessible people to the sample in the sampling scope where there are time or budget limitations in research (Gegez, 2019). Goodman (1961) emphasized that snowball sampling is a sampling to bring together all possible participants for a research or evaluation. It is applied in the case where finding potential respondents is strong (Goodman, 1961).

A questionnaire was conducted to respondents. The questionnaire consists of 56 questions including demographic and work experience questions and Likert scale questions for project management methodology evaluation for time, cost and quality metrics (Please see Appendix for a sample of the questionnaire). The survey was conducted online. 5-point Likert style was applied

for 46 project management methodology evaluation questions and rest of the questions were prepared in multiple choice styles.

Sample characteristics can be seen in Table 10 below.

Table 10: Sample Characteristics

Criteria	Attribute		Data Collected(210)		Data Utilized(161)	
			Number	%	Number	%
Gender	Women		89	42,4	74	46
	Men		121	57,6	87	54
Age	Above 40		32	15,2	24	14,9
	36-40		30	14,3	23	14,3
	31-35		76	36,2	59	36,7
	26-30		61	29	50	31
	25 or below		11	5,3	5	3,1
Education	Doctorate Degree		5	2,4	5	3,1
	Master's Degree		97	46,2	76	47,2
	Bachelor's Degree		104	49,5	77	47,8
	Associate Degree		4	1,9	3	1,9
Position	Project Manager		72	34,3	55	34,2
	Scrum Master		10	4,8	10	6,3
	Product Owner		10	4,8	9	5,6
	Technical Manager		20	9,5	15	9,3
	Team Leader		12	5,7	9	5,6
	Designer		5	2,4	2	1,2
	Analyst		15	7,1	14	6,8
	Developer		23	11	16	8,7
	Tester		12	5,7	11	9,9
	Architect		2	1	2	1,2
	Non-Technical Position		12	5,7	11	6,8
	Other Positions		17	8	7	4,4
Project Type & Size	Waterfall	Very Big	41	19,5	40	24,8
		Big	87	41,4	85	52,8
		Medium	29	13,8	27	16,8
		Small	10	4,8	8	5
		Very Small	1	0,5	1	0,6
	Agile	Very Big	23	11	23	14,3
		Big	65	31	65	40,4
		Medium	57	27,1	57	35,4
		Small	12	5,7	12	7,4
		Very Small	4	1,9	4	2,5

5.3 Data Collection

A questionnaire was used as the data collection tool in this research to reach all possible participants in restricted time and gathering a maximum number of responses through a systematic approach. Applying questionnaires in research provides high-speed data collection, reduces or eliminates costs, leads to large number of responses and ensures up-grade objectivity (Dudovskiy, 2018).

There were a total of 51 questions in the questionnaire including demographic and work experience related questions as well as scale items to measure performance of agile and waterfall projects in terms of cost, time and quality. The scale items were constructed from sources including PMI PMBOK ® 6, RMC Publications (2018), Gencer and Kayacan (2017), and Balaji and Murugaiyan (2012). The measurement scales were produced according to guidance of measurements of project management performance and value (Center for Business Practices, 2005).

5.4 Reliability and Validity

IBM Statistical Package for Social Sciences (SPSS) 23 was used to analyses data. First, reliability analyses were applied to measure the reliability degree of the three scales – cost, time and quality respectively. It is argued by Nunnally that if the result of reliability analysis, "Cronbach's Alpha value", is greater than 0.7, the scale should be accepted as reliable (Nunnally, 1978). Cronbach's alpha statistics for scales are presented in the "alpha" column in Table 11:

Table 11 : Factor Analysis Results and Reliability Statistics

	Factor Loadings-1	Factor Loadings-2	Average Variance	Cronbach Alpha
Cost Performance (KMO;0,884 - Bartlett's Test of Spherecity; Chi-Square: 1019,260- df;21 – p value; 0,000)			**73,750**	**0,939**
Total costs of project are reduced by chosen project management methodology.	0,882			
Analysis costs of project are reduced by chosen project management methodology.	0,762			
Design costs of project are reduced by chosen project management methodology.	0,828			
Development costs of project are reduced by chosen project management methodology.	0,902			
Testing costs of project are reduced by chosen project management methodology.	0,871			
Procurement costs of project are reduced by chosen project management methodology.	0,877			
Go live and maintenance costs of project are reduced by chosen project management methodology.	0,881			
Time Performance (KMO;0,863 - Bartlett's Test of Sphericity; Chi-Square: 966,185- df;15 – p value; 0,000)			**77,803**	**0,942**
General timeline of project is shortened by chosen project management methodology.	0,881			
Analysis timeline of project is shortened by chosen project management methodology.	0,828			
Design timeline of project is shortened by chosen project management methodology.	0,836			
Development timeline of project is shortened by chosen project management methodology.	0,906			
Testing timeline of project is shortened by chosen project management methodology.	0,927			
Acceptance and go live timeline is shortened by chosen project management methodology.	0,910			
Quality Performance (KMO;0,892 - Bartlett's Test of Sphericity; Chi-Square: 1669,157- df;45 – p value; 0,000)			**79,100**	**0,946**
Total quality of project is improved by chosen project management methodology.	0,835			
Integration quality of project is improved by chosen project management methodology.	0,717			
Analysis quality of project is improved by chosen project management methodology.	0,725			
Design quality of project is improved by chosen project management methodology.	0,695			
UX quality of project is improved by chosen project management methodology.	0,685			
Development quality of project is improved by chosen project management methodology.	0,935			
Testing quality of project is improved by chosen project management methodology.	0,914			
Security quality of project is improved by chosen project management methodology.	0,877			
Flexibility and extensibility quality of project is improved by chosen project management methodology.	0,807			
Documentation quality of project is improved by chosen project management methodology.		0,910		

Cronbach's Alpha values are greater than 0.7 for all three scales, therefore it can be accepted that all the scales are reliable.

It is stated by Büyüköztürk (2016) that the adequacy of the data for factor analysis can be examined by Kaiser-Meyer-Olkin (KMO) coefficient and Bartlett's test. If KMO result is greater than 0.5, the factor analysis is assumed to be applicable and once Bartlett's test result is less than 0.005 the data could be assumed as meaningful (Büyüköztürk, 2016). Before the factor analysis

which is required to measure the validity, KMO and Bartlett's Test were applied on to the data for cost, time and quality scales to understand whether the sampling adequacy is correct or not. Akgül (2005) argued that KMO test compares the magnitude of observed correlation coefficients with magnitude of partially correlation coefficients (Akgül, 2005).

The KMO value equals 0.884 and p equals 0.000 for cost; the KMO value is 0.863 and p is 0.000 for time; and the KMO value equals 0.892 and p is 0.000 for quality. Therefore, it is concluded that all the data is adequate for factor analysis. Therefore, factor analysis was applied to these three scales and results can be seen in Table 11. Cost and time scales were loaded on one factor and whereas in the quality item, two factors were revealed where only one item (item code: quality2) loaded on the second factor. The reason of why wfquality2 might have loaded to a second factor will be explained in the conclusions chapter.

5.5 Hypothesis Testing and Findings

Two project management methodologies, waterfall and agile, were evaluated in this study. Descriptive statistics for the variables can be seen in Table 12.

Table 12: Descriptive Statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
WFCOST	161	1,00	5,00	2,3842	1,08670	,655	,191	-,768	,380
WFTIME	161	1,00	5,00	2,3230	1,11066	,730	,191	-,738	,380
WFQUAL	161	1,00	4,90	2,6205	1,00338	,501	,191	-,930	,380
AGCOST	161	1,00	5,00	3,6140	1,11550	-,669	,191	-,910	,380
AGTIME	161	1,00	5,00	3,6729	1,09733	-,749	,191	-,707	,380
AGQUAL	161	1,00	5,00	3,5280	,97629	-,759	,191	-,482	,380
Valid N (listwise)	161								

Paired sample t tests were conducted to test the hypotheses. Results of the paired sample t test are shown in Tables 13, 14 and 15;

Table 13: Paired Samples Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	WFCOST	2,3842	161	1,08670	,08564
	AGCOST	3,6140	161	1,11550	,08791
Pair 2	WFTIME	2,3230	161	1,11066	,08753
	AGTIME	3,6729	161	1,09733	,08648
Pair 3	WFQUAL	2,6205	161	1,00338	,07908
	AGQUAL	3,5280	161	,97629	,07694

Table 14: Paired Sample Correlations

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	WFCOST & AGCOST	161	-,823	,000
Pair 2	WFTIME & AGTIME	161	-,804	,000
Pair 3	WFQUAL & AGQUAL	161	-,817	,000

Table 15: Paired Samples Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	WFCOST - AGCOST	-1,22981	2,10267	,16571	-1,55708	-,90255	-7,421	160	,000
Pair 2	WFTIME - AGTIME	-1,34990	2,09672	,16525	-1,67624	-1,02355	-8,169	160	,000
Pair 3	WFQUAL - AGQUAL	-,90745	1,88718	,14873	-1,20118	-,61373	-6,101	160	,000

There are three hypotheses for this research based on evaluation of criteria for cost, time and quality to compare the performance of waterfall and agile project management methodologies. In testing for hypothesis 1 (*H1: There is a significant difference between cost performance of waterfall and agile projects.*), pair 1 (WFCOST-AGCOST) was taken into

consideration and it was concluded that Hypothesis 1 was supported as the mean value was -1.22981, which was less than 0 and the significance was equal to 0.000. To test hypothesis 2 (*H2: There is a significant difference between time performance of waterfall and agile projects.*), pair 2 (WFTIME-AGTIME) was taken into consideration and it was concluded that Hypothesis 2 was supported as the mean was -1.3499 less than 0 and its significance was equal to 0.000. In testing for hypothesis 3 (*H3: There is a significant difference between quality performance of waterfall and agile projects.*), the pair 3 (WFQUAL-AGQUAL) was taken into consideration and it was concluded that Hypothesis 3 was supported since the mean was less than -0.90745 and its significance was equal to 0.000. When the results are evaluated for three pairs, it is seen that there are significant differences among the components of pairs. The pair 1's means are 2,3842 for waterfall and 3,6140 for agile, the pair 2's mean values are 2,3230 for waterfall and 3,6729 for agile, and the pair 3's mean values are 2,6205 for waterfall and 3,5280 for agile. From the perspective of cost, time and quality, it is proved by results that there are differences between two methods. It is superior to the agile waterfall according to all the three criteria, and provides higher performance on software projects.

6. CONCLUSIONS

Project management has taken its place in the life of human beings long before its definition, it has gradually matured, has been updated with the lessons learned and has come to the present day. Mankind has increased its areas of activity day by day by providing basic motives such as survival, shelter, nutrition and continuation of its generation and has started to progress in each of them and discover new areas. In each discovery or any update on existing elements, tools were used as facilitators and accelerators that have been invented and developed based on the learned information. As a result of this progress and also of invention of the computer, the main aim of humankind became channelizing all possible work packages to automated systems, focusing on new explorations or improving existing structures. At this point, machines, i.e. hardware, and especially software that makes it possible to dominate hardware, have now become one of the basic needs of humanity and have started developing with the human kind.

The main aim of this study is to investigate the impact of project management methodology on performance metrics of cost-, time and quality. To reach the most accurate sample, the survey was designed so as to include respondents that have experience in both waterfall and agile project management methodologies and who are working directly or indirectly in software sector. Results of the data analysis showed that agile was more effective an all three criteria (cost, time and quality) and all three of the research hypotheses were supported.

The usage of scrum, which is the most widely used agile framework in software projects and which is directly created and constantly updated by the software developers , has a significant effect on the superior performance of agile over the waterfall methodology in all three hypotheses. Because scrum and other agile applications have tight timelines to produce some increments on products or services, and they provide frequent feedback mechanisms from customers and other stakeholders. Thus, once any change occurs on the agreed scope, production team may easily adapt itself and the outcomes to it. It takes longer time in waterfall, generally after going live of outcome. So, the waterfall methodology extends timeline of project, increases costs and usually decreases quality.

An interesting outcome of the data analysis phase was that the items measuring quality performance loaded into two factors in the exploratory factor analysis (see Table 11). One item, "Documentation quality of project is improved by chosen project management methodology", loaded into a second factor. The application of the principle of documentation as much as necessary in the scrum method, which is generally applied, seems to be a deficiency due to the fact that those who produce and use the software do not come from the same background. However, as an advantage of agile, it has been transformed into a structure that causes loss of quality while being considered as a gain from time and cost. In order to prevent this, it is important to determine the basic documentation rules at the beginning of the project.

Current research findings are compatible with findings of previous studies highlighting that performance of agile project management methodology is superior to that of waterfall project management methodology. Despite that, the usage ratio of waterfall is still higher than agile's in software projects. Companies are reluctant to start using agile, because they have experience at waterfall and it is accepted as a tradition. Companies have formed their structure according to requirements of waterfall and have educated their personnel in the way of waterfall project management methodology. Due to the resources dedicated to waterfall methodology, it becomes harder for companies to transform their systems and structures in line with the requirements of agile methodology. The major reasons of deficiency on failure in agile transformation are having lack of research departments in companies, working conditions of companies which are so busy with not adequate number of personnel and under tight program, lacking management awareness of companies, organizational structure of company, resistance of staff, pre-justices about agile, misunderstanding of agile, the expenses which are required to transform the organizational structure, wrong evaluation that not finding the results as adequate to adapt to the new methodology, and the executives who have authority in company's strategical decisions and are used to work with waterfall are afraid of change.

Because of the digital transformation age, all the sectors are increasing their software products or services usage. Production teams generally work in different areas which have different business rules. At this situation, it could be effective forming the combination of waterfall and agile in same project with starting analysis as waterfall or separating analysis from development and going the analysis with another and non-stoppable sprints until the completion

of detailed and agreed analysis. Once the analysis outcomes are produced by project members, the sprints are launched for software development immediately. Thus, the business rules are totally understood by production team in a shorter time and the customer can have a chance to check the increments. This gives the chance to the project team members and stakeholders to review completed analysis periodically and to make possible changes without any type of doing scope creep or gold plating.

On the other hand, the type of contract is an important index in projects. According to PMI PMBOK ® 6, there are three contract types in project management. First and mostly used is fixed-term contract, second is time and material, and last type is the cost payback contract. All these three headings have sub contents but these are based on same principles in their group with little differences (Project Management Institute (PMI), 2018). In case of starting to work with new company or working on a new business area, production team's company should offer an analysis phase to the customer first. This will let the outsourced production team get used to the new work ethics or conditions of environment. After the completion of analysis and creation of requirements or user stories with all details and user acceptance criteria, the customer, who can be a person or a company, can organize a tender to collect the offers from other software development companies and can maximize value of the project outcome.

This thesis contributes to the literature by providing a detailed description and comparison for agile and waterfall project methodologies, showing their pros and cons, and by providing a detailed set of data showing results which are produced from software professionals' answers to the prepared survey. It will also be able to give an idea about the projects and which project management methodology would be appropriate for the projects to be implemented. The results may be useful for software companies and the software industry as they present a situation snapshotting. Results may also be used as a new baseline for new researches from different companies, work ethics and cultures.

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APPENDIX

Survey Questions

Demographic and Work Experience Questions

1- What is your age range?
   a. 25 or less
   b. 26-30
   c. 31-35
   d. 36-40
   e. Above 40

2- What is your gender?
   a. Female
   b. Male

3- What is your current position?
   a. Project Manager
   b. Technical Manager
   c. Not Technical Position (Customer, Sponsor, Stakeholder etc.)
   d. Teal Leader
   e. Software Developer
   f. Software Analyst
   g. Software Tester
   h. Software Architect
   i. Product Owner
   j. Scrum Master
   k. Designer
   l. Other

4- What is your education status?
   a. Associate Degree
   b. Bachelor's Degree
   c. Master's Degree
   d. Doctorate Degree

e. Other

5- How many years have you been working in current company?
   a. 2 years or less
   b. More than 2 years, up to 5 years
   c. More than 5 years, up to 10 years
   d. More than 10 years

6- How many years of total experience do you have in software sector?
   a. No Experience
   b. 2 years or less
   c. More than 2 years, up to 5 years
   d. More than 5 years, up to 10 years
   e. More than 10 years

7- How many years of Waterfall experience do you have?
   a. No Experience
   b. 2 years or less
   c. More than 2 years, up to 5 years
   d. More than 5 years, up to 10 years
   e. More than 10 years

8- If you participated in any waterfall project, what was the magnitude of the project (if you have participated more than one waterfall projects you should choose which type you participated most)
   a. Very Large (1200+ man/days or 24+ months)
   b. Large (600-1200 man/days or 9-24 months)
   c. Medium (300-600 man/days or 4-9 months)
   d. Small (100-300 man/days or 2-4 months)
   e. Very Small (0-100 man/days or shorter than 2 months)

9- How many years of agile experience do you have?
   a. No Experience
   b. 2 years or less
   c. More than 2 years, up to 5 years
   d. More than 5 years, up to 10 years

e. More than 10 years

10- If you participated in any agile project, what was the magnitude of the project (if you have participated more than one agile projects you should choose which type you participated most)

a. Very Large (1200+ man/days or 24+ months)
b. Large (600-1200 man/days or 9-24 months)
c. Medium (300-600 man/days or 4-9 months)
d. Small (100-300 man/days or 2-4 months)
e. Very Small (0-100 man/days or shorter than 2 months)

Project Management Methodology Questions

Waterfall Project Management

Costs Questions

No	Criteria	Answers
11	Does using waterfall in software projects reduces total costs?	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
12	Does using waterfall in software projects reduces analysis costs?	
13	Does using waterfall in software projects reduces design costs?	
14	Does using waterfall in software projects reduces development costs?	
15	Does using waterfall in software projects reduces testing costs?	
16	Does using waterfall in software projects reduces procurement costs?	
17	Does using waterfall in software projects reduces go live and maintenance costs?	

Time Questions

No	Criteria	Answers
18	Does using waterfall in software projects shortens general timeline?	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
19	Does using waterfall in software projects shortens analysis timeline?	
20	Does using waterfall in software projects shortens design timeline?	
21	Does using waterfall in software projects shortens development timeline?	
22	Does using waterfall in software projects shortens testing timeline?	
23	Does using waterfall in software projects shortens acceptance and go live timeline?	

Quality Questions

No	Criteria	Answers
24	Does using waterfall in software projects improves total quality	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
25	Does using waterfall in software projects improves documentation quality?	
26	Does using waterfall in software projects improves integration quality?	
27	Does using waterfall in software projects improves analysis quality?	
28	Does using waterfall in software projects improves design quality?	
29	Does using waterfall in software projects improves UX quality?	
30	Does using waterfall in software projects improves development quality?	
31	Does using waterfall in software projects improves testing quality?	
32	Does using waterfall in software projects improves security quality?	
33	Does using waterfall in software projects improves flexibility and extensibility quality?	

Agile Project Management

Costs Questions

No	Criteria	Answers
34	Does using agile in software projects reduces total costs?	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
35	Does using agile in software projects reduces analysis costs?	
36	Does using agile in software projects reduces design costs?	
37	Does using agile in software projects reduces development costs?	
38	Does using agile in software projects reduces testing costs?	
39	Does using agile in software projects reduces procurement costs?	
40	Does using agile in software projects reduces go live and maintenance costs?	

Time Questions

No	Criteria	Answers
41	Does using agile in software projects shortens general timeline?	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
42	Does using agile in software projects shortens analysis timeline?	
43	Does using agile in software projects shortens design timeline?	
44	Does using agile in software projects shortens development timeline?	
45	Does using agile in software projects shortens testing timeline?	
46	Does using agile in software projects shortens acceptance and go live timeline?	

Quality Questions

No	Criteria	Answers
47	Does using agile in software projects improves total quality?	a. Strongly Disagree b. Disagree c. No Decision d. Agree e. Strongly Agree
48	Does using agile in software projects improves documentation quality?	
49	Does using agile in software projects improves integration quality?	
50	Does using agile in software projects improves analysis quality?	
51	Does using agile in software projects improves design quality?	
52	Does using agile in software projects improves UX quality?	
53	Does using agile in software projects improves development quality?	
54	Does using agile in software projects improves testing quality?	
55	Does using agile in software projects improves security quality?	
56	Does using agile in software projects improves flexibility and extensibility quality?	

BIOGRAPHY

Aydın Gökhan Kahraman was born in Manisa, Turkey in 1990. He graduated from Istanbul Technical University Electronics Engineering Program in 2012 and started to work in the software industry. He worked as software developer, business analyst and project manager respectively. He holds PMP, PSM I and PSPO I certifications and has experience in both waterfall and agile methodologies. He managed domestic and international projects in different fields such as sports, ERP, heating, climate, aviation, finance etc.